SCIENCE ACTIVITIES

BOOK ONE

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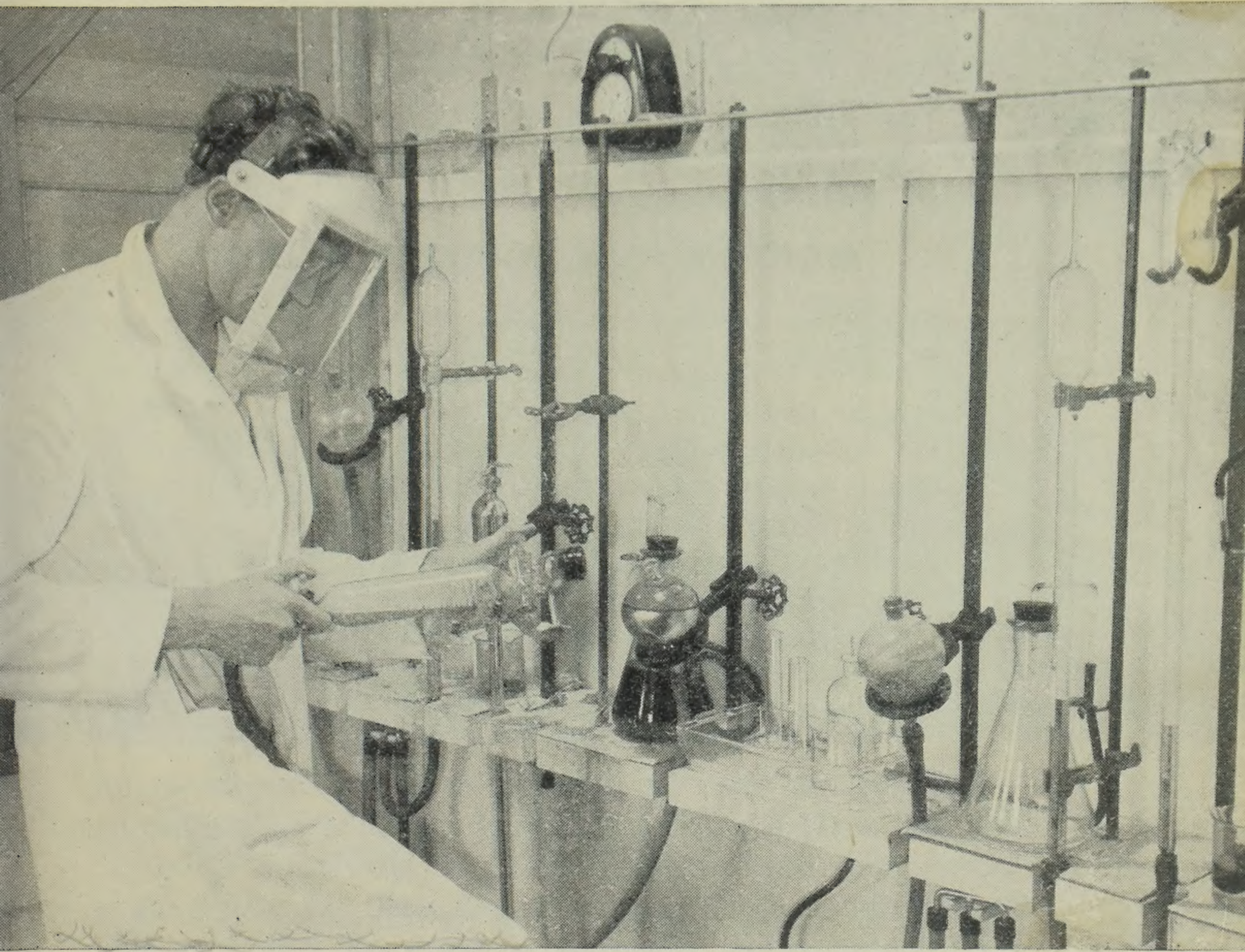

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The scientific method is only about four hundred years old, but it has already produced more facts and inventions than did all the previous four hundred thousand years of human progress. What the present scientific facts have done for the world, we see; what the scientific method will do for the future staggers the imagination.

—PHILIP B. SHARPE.

CHAPTER ONE

CHAPTER 1

MAKING A GOOD BEGINNING

Science is important to you. Why? Think what life would be like if there had never been scientists. How have scientists helped to provide you with food and clothing, to keep you healthy, to enable you to travel from place to place? What comforts and conveniences and what forms of recreation have they supplied you with? How have they made it possible for you to know about interesting things that have happened and are happening in the world to-day? How can *you* become a scientist?

Think back over the things that happen to you on an ordinary week-day. You wake up to hear your mother or father telling you it is time to get up. Outside it is still dark; but you simply push a button in your wall, and your room is flooded with light. Hundreds of years ago boys and girls had to dress by the dim light of candles, but since that time, Michael Faraday and many other scientists have performed many painstaking experiments and made many important discoveries. Now we know how to put electricity to work, and as a result, your house is bright on cold mornings when it is still like night out-of-doors. If you are a city boy or girl, when you go down to breakfast and pour yourself a glass of milk, you can be sure that there are no harmful germs in it, because the famous French scientist Louis Pasteur taught people that when they pasteurized milk they killed the germs. Because of the patient work of other scientists you can turn on the radio and hear the latest news, or telephone one of your friends and make plans for the day, or ride to school in a motor

In this illustration there are at least twelve objects that have been produced and improved by scientists and inventors. How many of them can you find? (Canadian General Electric Co. photo)

bus. The food you eat, the house you live in, the clothes you wear have been developed after long years of careful scientific experimenting.

But science can do more than this for you. It can teach you not only to appreciate what other scientists have done, but also to be a scientist in the things you do yourself. If you look at things carefully to see what they are like, and ask yourself what makes things happen the way they do, you have a scientific attitude. You can learn the scientific method of making experiments and finding the answers to your questions.

Ever since the time of Galileo, scientists have been working out a "method of attack," a way of finding out the basic truth of things, which is known as *the scientific method.* This method has been proved to be reliable and accurate. It is possibly the greatest contribution that scientists have made.

The pilots of these machines are dropping flares to light up the area below them. Make a list of scientific inventions and developments that are evident in this scene. (Canadian Industries, Ltd. photo)

THE SCIENTIFIC METHOD OF SOLVING PROBLEMS

On their way back to school one noon-hour, George Alton and Earl Williams heard the heavy droning of a great motor, and stopped to watch a plane flying far overhead. As they walked on talking about it, they suddenly wondered what enabled a massive machine like an aeroplane to stay up in the air. None of their friends at school could account for it either, and in the science class that afternoon one of them asked Miss Peterson to tell them what made it possible. Miss Peterson suggested that they all work together and try to solve their problem by the scientific method.

"If we are going to do this by the scientific method," she said, "what must be our first step?"

1. The pupils agreed that *the first step is to define clearly the problem to be solved.* After some discussion, it was agreed that their immediate problem was: What keeps an aeroplane in the air?

2. *The second step in the scientific method is to recall past experience and look for new information that may help to solve the present problem.* John Bourne remembered that a paper dart will remain in the air as long as it is moving. George Alton, who used to fly a kite, told how he used to feel a pull on the string, as if something were pushing at the kite, holding it up in the air.

3. *The third step in the scientific method is to suggest, discuss, and criticize possible solutions, finally selecting the most likely*

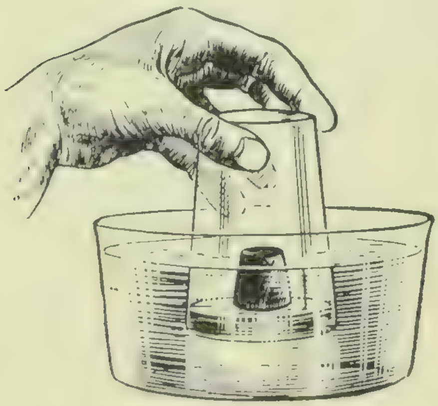
This scientist is using a powerful compound microscope that is capable of magnifying an object as much as two thousand times. With the aid of such instruments, scientists have made many important discoveries affecting our health and well-being. (Bausch & Lomb Co. photo)

one to be tested by experiment or investigation. John Bourne thought that, since the paper dart stayed in the air as long as it was moving, an aeroplane was kept up by the speed at which it travelled. But Mary McDonald did not agree. Motion might keep a very light paper in the air, but it was not enough to prevent a stone from falling even if it was thrown swiftly; surely, then, speed alone was not enough to make an aeroplane weighing several tons stay in the air.

Earl Williams found a paragraph in a book which explained that it is the pressure of the air that keeps a kite up. Therefore he argued that the pressure of the air enabled an aeroplane to fly. This idea was accepted with favour until Kay Johnston said: "How can the air exert pressure when it is just empty space?"

"You only think that air is just empty space," said Earl. "If we can prove by experiment that air exerts pressure, you will have to agree that air pressure may be what keeps an aeroplane in the air."

4. All the pupils were willing to follow this plan. They were then proceeding to *the fourth step of the scientific method, namely, carrying out an experiment or investigation to prove or disprove the most likely solution proposed in steps 2 and 3.* The class performed several experiments. Their first experiment was performed to find out if Kay Johnston was right when she said that air was just empty space.



What prevents the water from rising farther into the tumbler?

Something to Do

This is a description of the first experiment the class performed. Follow the instructions, and discover for yourself whether air occupies space.

Problem.—Does air occupy space?

Apparatus and Material.—A glass tumbler; a vessel (a dishpan will serve) filled with water; a cork.

Method.—(1) Float a small cork in a vessel of water. (2) Place a glass tumbler, mouth down, over the cork, and push the tumbler into the water. (3) Watch the cork to see if the water rises in the tumbler.

Observations.—Has the water risen to fill or nearly fill the tumbler?

Conclusion.—If the water did not rise to fill the tumbler, why didn't it? What occupies the space inside the tumbler, thereby keeping the water out?

Now answer the question asked in the problem which the pupils were trying to solve: Does air occupy space?

Like you, the class had proved that air occupies space. Anything that occupies space, Miss Peterson told them, is a form of matter. Therefore air is a form of matter. The various kinds of matter are known as substances. Iron, copper, wood, paper, and water are examples of substances. Air, too, is a substance.

Kay Johnston, who had always taken it for granted that air was nothing, was surprised to find out so much about it. She remembered that, although you could not see air, you could feel it when it was in motion.

"Scientists have discovered other evidences of its presence, too," said Miss Peterson, "and they have found out a great deal about it. For example, all forms of matter have weight; it can be shown that air has weight."

These boys are using the experimental method to find out for themselves facts about air pressure. What step of the scientific method does this illustrate?

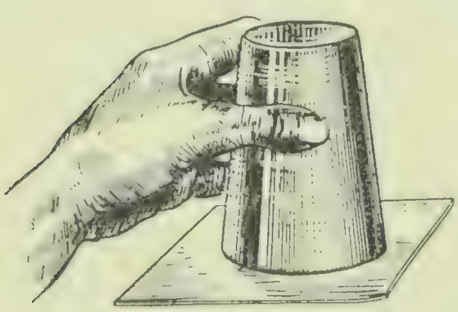
Some of the pupils wanted to do an experiment to prove that air has weight; but they changed their minds when George reminded them that their problem was to find out what keeps an aeroplane in the air. They decided to continue by the scientific method to try to prove whether, as Earl had suggested, air exerts pressure.

Miss Peterson said there were a number of experiments they could perform to solve this problem. The class divided into groups, and each group did an experiment.

The first group filled a tumbler to the brim with water. Then one boy held his hand tightly over the mouth of the tumbler, turned it mouth down, and lowered it into a basin of water until the mouth of the tumbler was just below the surface of the water. He then slipped his hand out, and the group watched to see if the water would run out into the basin or stay in the tumbler. They observed that the water

stayed in the tumbler. They reasoned that, if it had run out, the level of water in the basin would have risen. Since it didn't run out, something must have been pressing down on the surface of the water in the basin to keep it from rising. There was nothing above the basin but air. Therefore, the first group concluded that the air was exerting the pressure.

The second group took scissors, a piece of thin cardboard, and a tumbler. They cut from the cardboard a piece about an inch larger all round than the mouth of the tumbler. Then one pupil filled the tumbler to the brim, set the cardboard over the mouth of the tumbler, and holding it firmly in place, turned the tumbler upside down. Carefully he removed his hand from under the cardboard. The group observed that the water stayed in the tumbler, and that the cardboard remained in place. They concluded that air must be pressing against the cardboard to hold it in place, and therefore that air exerts pressure.



What prevents the water and the card from falling from the tumbler?

In the third group, a girl inserted the tube of a medicine dropper into a glass of water. She squeezed the bulb. Then she released it. When the bulb was squeezed, the pupils saw bubbles of air forced out of the tube into the water. When the bulb was released, they observed that water rose in the tube to replace the escaped air-bubbles. They asked themselves why water had risen in the tube of the medicine dropper, and concluded that it had been forced up by the pressure of the air on the water in the glass.

The fourth group did their experiment with a flask of water, a one-holed rubber stopper or cork, and a glass tube. First, a pupil inserted the tube into the open flask, and sucked some of the water through it. Then he inserted the tube through the hole in the stopper, fitted the stopper on the

flask, and tried to suck the water up the tube again. Everyone in the class could see that it was easy for him to suck water into the tube from the open flask, but impossible to do it from the stoppered flask from which the air had been shut out. They decided that water cannot be raised into a tube by suction alone. They concluded that air pressure on the surface is the force that raises the water up into the tube.

The fifth group experimented with paper bags. Each pupil closed the mouth of his bag around his finger. Then he removed his finger and through the small opening blew air into the bag. Then he sucked air out. The pupils saw the bags swell when air was blown in, and crush when air was drawn out again. They concluded that the bags swelled when they blew in because the pressure of the air pushed on the inside of the bags, and crushed when they sucked the air out because the pressure of the air all around was pushing on the outside of the bags.

The sixth group assembled the following equipment: a milk bottle, a four-inch square of paper, a match, an egg, a saucepan of water, and a burner. They lit the burner and boiled the egg for about ten minutes. One girl removed it from the saucepan, cooled it in water, and peeled it, while another made sure the milk bottle was quite dry. Then a third pupil twisted the square of paper, set fire to it, dropped it into the milk bottle, and quickly placed the egg in the neck of the bottle. The group watched the paper burning and saw, when the fire went out, that the egg was pushed down into the bottle. They could not decide what had happened until Miss Peterson explained that air expands when heated, and contracts when cooled. Then they concluded that the fire had heated the air inside the bottle until it expanded, and some of it escaped past the egg. When the fire went out, the air cooled again, and contracted. The pressure of the air outside the bottle was then greater than the pressure inside, and the egg was pushed into the bottle.

NOTE.—The egg can be forced out of the bottle again by turning the bottle upside down and pushing the egg until the charred paper falls out, then blowing vigorously into the bottle while it is still upside down.

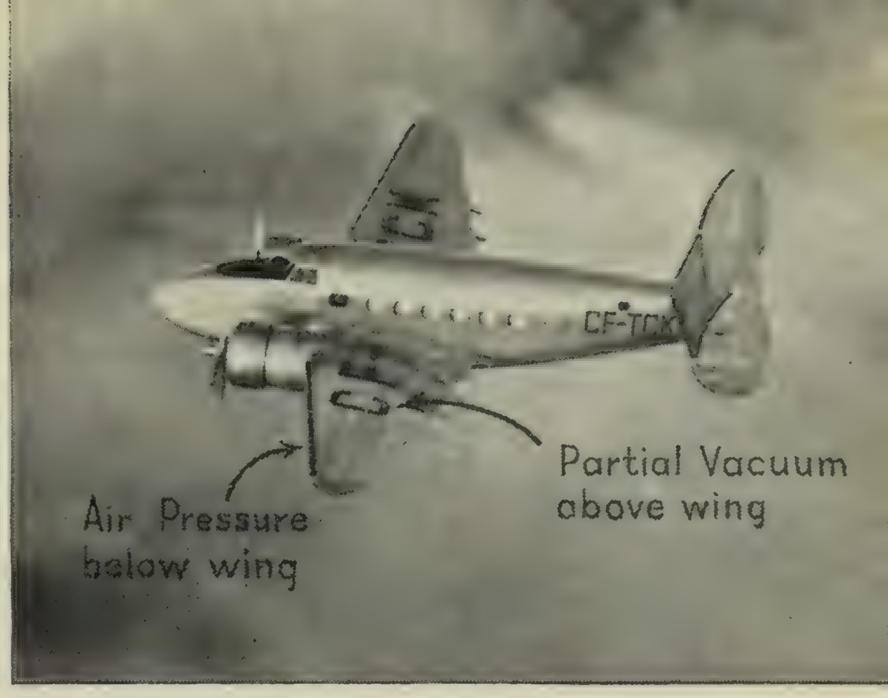
The members of each of the six groups prepared a report on the experiment they had performed, to be read to the whole class. They had completed the fourth step of the scientific method. Earl had argued that it was air pressure that kept an aeroplane up. The class had carried out experiments to test his argument.

5. *The fifth step of the scientific method consists in examining the results of the experiments and arriving at a conclusion.* When the reports were read, the class found that each experiment had proved the same thing. They were able to conclude that air is a real substance and that it does exert pressure.

"But we still haven't proved that air pressure is what keeps an aeroplane in the air," said John Bourne. "We have proved that air exerts pressure. But there is air around houses and people and everything, and they don't stay up in the air."

Miss Peterson agreed that John was right in his argument that air pressure alone cannot keep an aeroplane in the air. But their problem was a very big one, she said, and working out the whole solution would take a great deal of time. Therefore they should take advantage of the work done by other scientists and recorded in reliable books. She then directed them to a book in which they found the following explanation: The speed of a plane through the air causes a partial vacuum (văk′ū-ŭm) directly above the wing. (A vacuum is a space where there is no air.) Beneath the wing the air pressure is pushing upward. Consequently there is much less pressure of air above the wing than there is below it. As a result, the air pressure exerts a strong lifting force on the wing. Therefore speed and air pressure combine to keep an aeroplane in the air.

Miss Peterson explained to the pupils that they were not departing from the scientific method when they consulted this book. Every scientist profits by the work of the scientists before him.



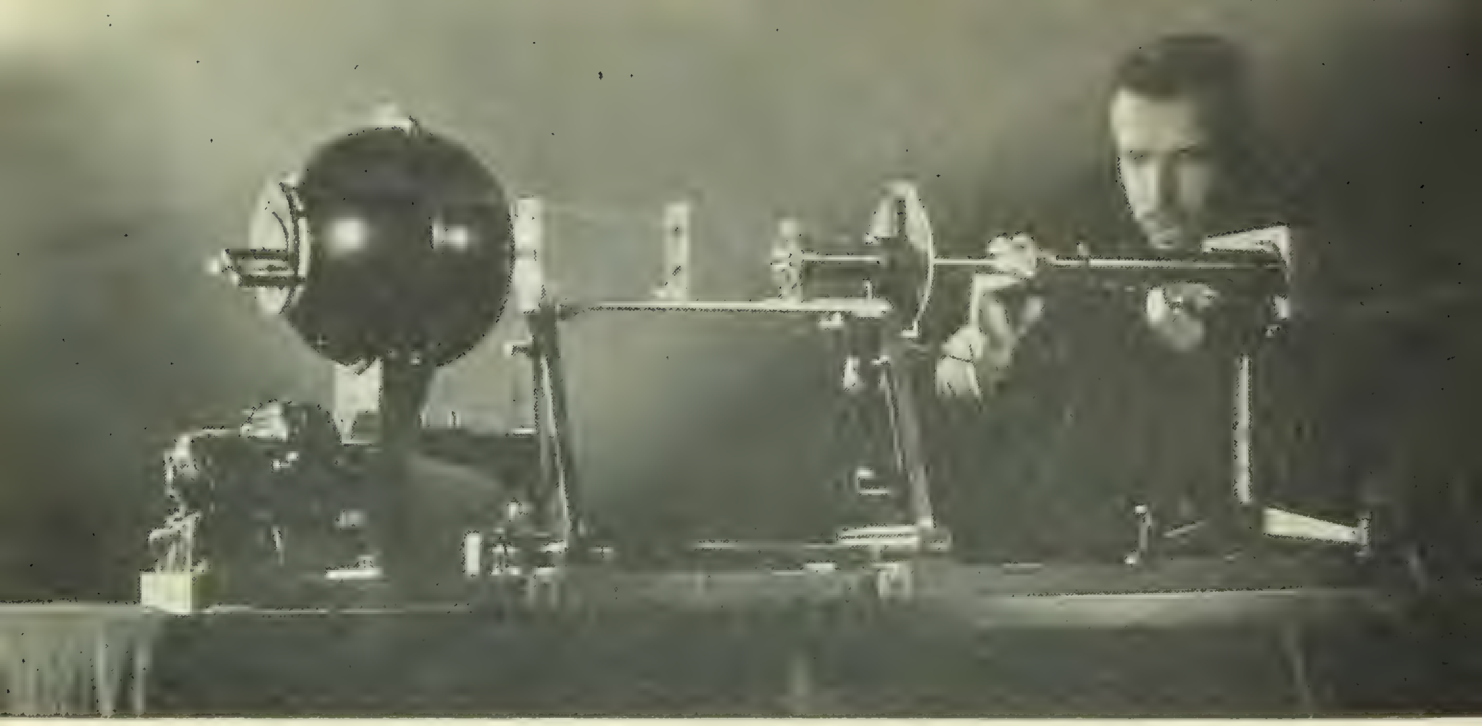
A Trans-Canada air liner in flight. What keeps this heavy machine in the air? (Trans-Canada Air Lines photo)

"But," said Miss Peterson, "you have not yet taken the final step in the scientific method. Scientists are not content to stop when a solution to a problem has been reached. They continue their investigations to prove that their solution is correct."

6. *The sixth step in the scientific method is to test the solution for its accuracy in other situations and to obtain further information if possible.* Through the days that followed, the class went on studying air pressure and learned many facts about it. They found out, for example, that air presses against buildings and people with a force of about fifteen pounds on every square inch; and that water can be raised in a pump by air pressure. Their knowledge of air pressure was useful in explaining many things that they had formerly taken for granted.

WHAT IS AN EXPERIMENT?

We have seen that there are six steps in the scientific method of solving problems. In the fourth step, if possible, an experiment is performed. An experiment, therefore, is only one step in the scientific method. It is an excellent way to find the correct answer to some particular question. As we have seen, by experimenting the class found the answer to the question: Does air occupy space?



This scientist is experimenting with light, using his spectrophotometric apparatus, by means of which he can measure very accurately the strengths of different light sources. Scientists often use very elaborate equipment in making new discoveries. (Bausch & Lomb Co. photo)

In performing an experiment six steps must be taken. Let us examine the steps and determine whether, in the experiment on page 6, the class followed the correct procedure.

1. *Problem.*—What you want to know. The class wanted to know whether air occupies space.

2. *Apparatus and Material.*—What you use in performing the experiment. The class assembled all the materials that were needed—tumbler, a deep pan filled with water, a cork.

3. *Method.*—What you do. (1) The pupils floated the cork in the pan of water. (2) They placed the glass tumbler, mouth down, over the cork, and pushed the tumbler into the water. (3) They watched closely to see whether water would rise in the tumbler.

4. *Observation.*—What you see. The pupils observed that the water did not rise in the tumbler.

5. *Conclusion.*—What you learn. The pupils reasoned that water could not rise to fill the tumbler because the tumbler was already full of air. They learned therefore that air occupies space.

6. *Application.*—What use you make of your discovery. Having learned that air and other matter cannot occupy the

same space at the same time, the pupils now understood that if you want to fill a bottle or other container, you must let the air out. They used this knowledge on many occasions.

Whenever you perform an experiment, always follow the plan outlined on the opposite page. Whenever you record an experiment in your note-book, arrange your notes under the six headings shown there.

Review Questions and Exercises

1. List in correct order the six steps of the scientific method as they are described on pages 4 to 11.
2. Explain the difference between the scientific method and an experiment.
3. Try for yourself several of the experiments described on pages 6 to 10, and using the six headings given on page 12, record your experiments in your science note-book.
4. Show how the scientific method avoids the dangers of mere guessing.
5. "More important than all the new inventions and discoveries is the scientific method." Do you believe that this statement is true? What arguments can you give in support of it?

Something to Do

1. Plan and perform an experiment to prove that potatoes contain starch. Write a complete report of it in your note-book under the usual six headings.
2. Which is heavier, milk or cream? Solve this problem by the scientific method. Describe to the class each of the six steps you follow, and prepare a written report of the fourth step —the experiment.

WHAT IS A SCIENCE PROBLEM?

Everyone has many problems to solve every day. The thinking person recognizes the problem that faces him and works out the most satisfactory solution he can. It will help you to recognize your everyday problems if you make a list

of the problems you had to solve in one morning; for example: What time shall I get up? What clothes shall I put on? Shall I ride my bicycle to school, or walk? What library book shall I read? How can I use my spending money to best advantage?

Every time a question arises that you cannot answer, you are facing a problem. Every time you decide which of several things you will do, or which of several ways you will do it, you are solving a problem. The successful solution of simple everyday problems may mean the difference between success and failure, between happiness and disappointment. You have learned the scientific method of solving problems. By using it you can find the best solution to the problems that face you every day.

A science problem is a question or a situation that presents a difficulty in the field of science. You are faced with science problems on every hand. You observe things that puzzle you, and you ask questions about them: Why do most trees shed their leaves when cold weather approaches? Where does the frost come from that forms on branches and telephone wires on winter mornings? When you stir your hot tea, what makes the spoon handle hot? Or you have a problem of action to solve: How can you grow winter blooms from bulbs? If you have a heavy load to move, how can you lighten your work? These and other problems are discussed in this book.

Every science problem that is solved helps human beings to live and work better and more wisely. In 1941 an epidemic of sleeping sickness, or encephalitis (ĕn-sĕf-al-īt′ĭs), threatened to break out in the Prairie Provinces. What caused it, and how could it be stopped? Men worked on this problem by the scientific method. They remembered that for several years many horses on the prairies had been attacked by a disease known as encephalomylitis. They reasoned that there might be some connection between the disease attacking the people in 1941 and the disease that had been attacking horses pre-

viously. It was suggested that mosquitoes were carrying the disease from horses to humans. What would be the value of continuing, by means of the scientific method, to find the solution of this particular problem?

Prize platinum foxes. Many scientific problems regarding breeding, selection, care, and feeding had to be solved in order to produce such excellent animals. (New Brunswick Government Information Bureau photo)

You have already thought of many inventions that have made your life simpler and happier. These are a result of the solving of some scientific problems. But there are many problems that nobody has been able to answer yet, and some things that have been explained only in part. Any boy or girl interested in science who learns to think and work scientifically may have the privilege some day of helping to find the solutions of some of the science problems that will make life simpler and happier for the people who live after him. There are many great examples for you to follow. The stories you will read on the next few pages tell about the lives of two men whose scientific way of living and thinking and working led them to great achievements.

THE STORY OF LEEUWENHOEK

Leeuwenhoek (lā′ven-hŏŏk) was born in Holland in 1632. As a young man he developed the hobby of grinding glass lenses or magnifying glasses, which make things look larger than they really are. He became the best lens-grinder of his day. By using several of his lenses together he made a microscope that was better than any other magnifier in existence.

Leeuwenhoek at work in his laboratory, where he discovered microbes. He used a simple microscope that he made for himself. Compare Leeuwenhoek's simple microscope, which he is holding in his hand, with the modern one illustrated on page 5. (Bausch & Lomb Co. photo)

Leeuwenhoek was filled with curiosity. Through his new microscope he examined everything he could find. He looked at spider webs, bee stings, hairs of animals, and was amazed at what he saw. One day he put a small live fish into a narrow tube of water, and looked at its tail through his microscope. He saw the fine branches of the arteries and the veins. And then he saw something else, something he did not expect to see. There were fine, hair-like vessels connecting the veins and arteries. We call them *capillaries*. Nobody had ever known that capillaries existed. By finding them, with the aid of his microscope, Leeuwenhoek had made an important

discovery about the circulation of the blood—a discovery that meant much to the development of medical science.

But Leeuwenhoek's greatest thrill came when he discovered a new world—the world of microbes. One day he scooped up some water from a puddle and focused his microscope on it. He was astonished to see that the water was teeming with life. There were little animals, or "beasties" as he called them, swimming, rolling, and playing about in the water. They were so small that one hundred of them laid side by side would not reach across the head of a pin. There were many one-celled plants, too. These tiny animals and plants are known as *microbes*. Leeuwenhoek's curiosity was greater than ever. He looked for microbes everywhere, and everywhere he found them. He tried to find out more about microbes by experimenting. In material he scraped from between his teeth he saw hundreds of microbes in various sizes and shapes. But when he examined material from the same source again, after drinking a cup of hot coffee, he could not find a single microbe in it. Further experimenting proved that extreme heat kills the "little beasties."

Other scientists followed up the work of Leeuwenhoek and discovered that some microbes are among man's best friends, and some—disease bacteria, for example—are his worst enemies. It was Leeuwenhoek, however, with his improved microscope, who opened the door into the world of the microbes. Exploration in that world has revealed the causes and led to the conquest of many diseases.

THE STORY OF MARCONI

Marconi was born in Italy in 1874. Even in his boyhood he was greatly interested in experimenting with electricity. At twelve years of age he was learning about the wonders of electromagnetic waves, which had recently been discovered by Hertz. He wondered if it might be possible to use these waves to send messages through space. Marconi dreamed that some

day these magic waves, travelling with the speed of light, would carry messages from ship to ship and from one continent to another in a very small fraction of a second.

With this dream in mind, Marconi began to experiment. At opposite ends of his father's garden he set up tall poles. On the top of each he attached strips of tin to serve as aerials. To the tin plate that was to be the sending aerial he connected an induction coil by means of which electromagnetic waves (or radio waves) were sent out into space. The receiving aerial was grounded by running a wire from the tin plate down into the ground. For a receiving instrument Marconi used a simple spark-gap resonator connected with the receiving aerial. With this instrument he succeeded in picking up the electric waves from the sending aerial and changing them into sound.

Encouraged by his first success, young Marconi continued to experiment. His ambition was to transmit messages by *wireless telegraphy* for hundreds of miles. By experimenting he improved the instrument for receiving the wireless or radio waves, and found that higher aerials gave better results. With this improved apparatus he was sending signals a distance of two miles or more by 1896. This marked the beginning of the use of the radio.

The following year Marconi went to England, where he demonstrated his invention by sending wireless messages from the Isle of Wight to the mainland. His next demonstration showed how wireless sets could be used to send messages from ship to ship and from ship to shore. In 1899 he communicated successfully with a receiver on the other side of the English Channel. Great interest was aroused when movements of British warships in a sham battle were directed by wireless.

Marconi continued to experiment and to improve his instruments. On December 12, 1901, his fondest hopes were realized when he succeeded in sending messages from England to Newfoundland. The radio waves had carried across the Atlantic!

Marconi with his "wireless" of 1897. This set was very different from our radios of to-day. It was capable of transmitting messages by dot and dash signals only. (Bettmann Archive photo)

Marconi's success was largely due to the fact that he worked by the scientific method. He had a clear idea of what he hoped to accomplish, namely, to discover a method of sending messages long distances by wireless telegraphy. To throw light on his problem, he read about the work of other scientists. From several possible solutions he selected the one that appeared to him the most promising—the use of electromagnetic waves. He tested his ideas by experiments. He improved his instruments and tested them, again and again. He worked hard and systematically. He never lost sight of his goal—long distance transmission of messages by wireless—until it was reached.

So rapid was the progress in the field of wireless telegraphy that in a few short years radios were bringing music and news bulletins to millions of listeners all over the world. New and better instruments gradually replaced the ones Marconi

originally used. Almost every year sees the introduction of some improvement. To-day it is possible to carry on a two-way conversation by means of short-wave radio between such widely separated countries as Canada and England.

Review Questions and Exercises

1. What is a science problem?

2. Show clearly how you would apply the scientific method to solving any one of the following problems:

(*a*) What shall I buy Mother for Christmas?

(*b*) At what hour should I start for school in the morning?

(*c*) What shall I prepare for supper?

3. State clearly and briefly one problem with which scientists were faced in connection with encephalitis in 1941.

4. (*a*) What important discoveries were made by Leeuwenhoek? (*b*) What problems did he face?

5. (*a*) Tell in your own words the story of Marconi's invention and improvement of wireless telegraphy.

(*b*) Show that Marconi used the scientific method in solving his problems.

Something to Do

1. Make a list of at least five everyday problems that you had to solve during the past week.

2. Make a list of famous scientists, and briefly state an important contribution made by each. See page 119 for suggestions.

3. Bring magnifying glasses to school, and show how they make things look larger than they are. Remember that a microscope is just a combination of magnifying glasses or lenses.

4. Read stories about the life and work of some of the great men of science, and tell your class about them. Suitable stories may be found in such books as: *Masters of Science and Invention* by Floyd L. Darrow, Harcourt, Brace & Co.; *The Boys' Own Book of Great Inventions* by Floyd L. Darrow and Clarence J. Hylander, The Macmillan Company of Canada; *Our Environment—How We Use and Control It* by George C. Wood and H. A. Carpenter, Allyn & Bacon; *Makers of Progress* by W. L. and S. H. Nida, Copp, Clark Co., Ltd.

THE SCIENTIFIC ATTITUDE

An *attitude* is a way of behaving or thinking. A person who follows the scientific method in reaching conclusions develops a scientific attitude.

The following are the qualities of a person who has the scientific attitude:

1. He *is curious, full of the spirit of inquiry.* A curious, inquiring person notices the things about him, and wonders about the *why* and the *how* of them. Curiosity and inquiry are the very basis of all learning. If you have ever watched a baby as he grows up, you will realize this. When he is born, he knows nothing about the world. But he is curious, and he learns quickly. He examines his hands and feet; he feels his toys and tries to put them into his mouth; he watches his ball roll; he listens to the sound of his rattle or the clank of his spoon on his plate; he learns to distinguish some objects by their odour. By the time he is a year old, a baby has learned many things about his environment by using his senses: by touching, tasting, seeing, hearing, and smelling things. As soon as he learns to talk, he begins to ask questions about things. Why is this? How did it happen? What is that? The child who continues to be curious—to want to find things out for himself—is well started on the road to learning.

Dr. Edward Jenner (1749-1823) discovered how to protect people from small pox by vaccination. This scientific discovery has saved the lives of millions of persons. (Metropolitan Life Insurance Co. photo)

Curiosity is the starting point of all science and all advancement. When George Alton and Earl Williams wondered what made the aeroplane stay up in the air, they had started by the scientific method towards the discovery of a truth. Leeuwenhoek, looking at water through his microscope, saw the microbes moving, and asked himself what they were; as

a result, men found that many diseases could be prevented by destroying certain of these microbes. Marconi was curious about sound and electromagnetic waves, and his curiosity was the first step in the development of the radio. Human progress, in large measure, has been dependent on man's curiosity—his desire to know.

2. A man who has a scientific attitude *finds out as many facts as he can and bases his thinking and decisions on facts.* He does not jump to conclusions. No wise person is satisfied with guesswork or hearsay. For example, when a cunning advertiser claims that a certain medicine is superior to any other and can work marvels, the unthinking man takes his word for it. But the man with the scientific attitude will not believe extravagant claims without checking them. He will demand to know the facts of the case: what the medicine is made of; how it is prepared; in what way it corrects the ailments the advertiser mentions. The man who jumps to conclusions may waste his money on a useless article, or even injure his health with the medicine; but the man with a scientific attitude will not buy the medicine unless the facts have convinced him that it is beneficial.

3. The man with a scientific attitude *is open-minded. He is willing to change his opinion when confronted with new facts about a question. He will desire the truth regardless of personal opinion or prejudice.* When the science class began their experiments with air, Kay Johnston thought air was just empty space, but when the experiments proved the fact that air occupies space and exerts pressure, she took a scientific attitude, and altered her original opinion to fit the new facts. Lou Baker, another member of the class, had several warts on his hands. He had heard that toads cause warts; and because he believed it, he loathed them and would not touch one. The class studied toads and learned that they are very beneficial because they eat large numbers of harmful insects. Superstitious people have the foolish idea that they cause warts

because of the warty appearance of a toad's skin, but the class proved that this idea is false. Lou Baker no longer loathed toads. He even learned to watch them at work in the garden, and became very interested in them. He showed a scientific attitude in changing his opinion of toads to agree with the facts.

4. The person who has a scientific attitude *knows that all occurrences are governed by natural laws. He knows that for everything that happens there is a cause.* In the following story of an occurrence, two explanations are suggested. Which is the more scientific?

A man is walking along the street when a black cat crosses in front of him. At the next intersection he stubs his toe on the curb, falls, and breaks his glasses. He may account for his accident in two ways. (1) He may say that it happened because bad luck was bound to come after a black cat had crossed his path. (2) He may recall the fact that at the corner he did not raise his foot high enough to clear the curb, and fell; his glasses struck the hard pavement and broke. With the facts of the case clearly in his mind, he may reason that the accident was an occurrence governed by the law of cause and effect. Meeting a black cat is not always followed by a fall. Failing to clear an obstacle (the curb, in this case) is *always* followed by a stumble or a fall. Therefore the cause of the fall was his careless step at the curb, not the meeting with the black cat.

If the man were to accept the first explanation, he would be jumping to conclusions; he would be taking a superstitious attitude. If he were to accept the second explanation, which was reached by examining the facts and using a knowledge of natural laws, he would have a scientific attitude. A man with a scientific attitude knows that superstitions are foolish. He does not believe in wearing good-luck charms. He knows that breaking a mirror, or walking under a ladder, or the number thirteen does not bring bad luck. Whatever happens, pleasant or unpleasant, happens as a result of a natural cause.

To sum up: If you have a scientific attitude you are curious, full of a spirit of inquiry. You base your thinking and your decisions on facts. You are open-minded. You understand the natural laws, and you find the explanation of occurrences by applying them.

Review Questions and Exercises

1. What four qualities mark a person with a scientific attitude? Describe four situations in each of which you show that you possess one of these qualities.

2. Make a list of some "signs" of good luck and of bad luck. Show how each one of the signs is a superstitious belief, not a scientific truth.

3. When a man has been very successful in life, you may hear someone say: "He must have been born under a lucky star." What do you think of this statement? Is it based on fact? Is it likely to be spoken by a person with a scientific attitude?

HOW CAN YOU INCREASE YOUR KNOWLEDGE OF SCIENCE?

1. *Learn by experimenting.* You can increase your knowledge of science by constantly practising the scientific attitude, by watching for scientific problems and by solving them by the scientific method. It is often possible, you remember, to perform an experiment as part of the scientific method. Marconi, the Wright brothers, Faraday, Edison, and many other great men gathered material for their inventions by experimenting. In the course of your discoveries, you too should learn the art of planning experiments carefully and performing them accurately.

2. *Learn from first-hand observation.* Curiosity is the basis of the scientific attitude, and observation is the beginning of all knowledge. It is very fine to read, for example, about our wild flowers in a good magazine or book. It is much better, however, to go out into the great out-of-doors and observe and study these flowers where they grow. You may read

in a newspaper about the harmful effects of water erosion; but if you go out to a field that has been washed into little ditches by running water, you will see the results for yourself, and have a much clearer understanding of the problem involved.

A tour of a creamery to see milk being tested, pasteurized, and bottled, or butter being churned and packed, will give you much up-to-date information about the way these important foods are handled to safeguard our health. A boy or girl who has always lived in the city can learn a great deal of science by visiting a farm, and observing at first hand the soil and variety of crops, the breeds of farm animals, and the various types of farm machinery. The boy or girl from the farm likewise can learn much by a visit to the city, where there are street-cars, factories, broadcasting stations, airports, and departmental stores, all offering many opportunities for observing scientific inventions.

Making observations of your own is an interesting method of studying science.

Fortunate indeed is the boy or girl of the prairies who has had an opportunity to travel and to see such wonderful sights of nature as mountains, rivers, lakes, oceans, waterfalls, canyons, forests, and fruit orchards. But his companion who stays at home is not less fortunate if he has eyes that see and a mind that understands, for many of the most interesting things in nature can be found in his own back yard. Let us, then, keep our eyes wide open and our ears tuned to nature, lest we miss some of the best things in life.

Apple blossoms like these are produced only on healthy trees. Fruit growers find it necessary to spray their fruit trees with chemicals to protect them from plant diseases and insect pests. The chemicals used are prepared by scientists. (Canadian Industries, Ltd. photo)

3. *Learn by reading.* It is impossible for you to repeat all the experiments that scientists have performed, or to solve all problems. Even though you long to do so, you cannot possibly explore all parts of the world from the depths of the ocean to the mountain peaks, to observe at first hand the many wonders of nature. Therefore, you will have to depend upon reading for much of your information about science. Scientific magazines and books open a wide world to you. New discoveries are continually being made. Scientists are finding new and better methods of using the forces and materials of nature. Stories about them may be found in newspapers and magazines from week to week. You should be on the alert for such up-to-date information.

4. *Learn by inquiring of those who know.* When observation, investigation, and reading fail to bring to light the particular information you want about a science problem, you should try to obtain it by discussing the subject with someone who has a knowledge of it. Suppose, for example, you find a strange butterfly in your garden. You note its size and markings. You search through the best insect book available, but fail to find what kind of butterfly it is. The wise thing to do then is to take it to someone in your neighbourhood whose hobby is the study of insects, and who will no doubt be able to identify the butterfly. He will be glad to help you and will probably enjoy telling you many

interesting stories about insects. You will find it helpful, and pleasant as well, to discuss your problems with other people who are interested in them.

These four methods of studying science overlap, and one usually leads to another. Making first-hand observations often leads to reading and to discussion with others; and reading may lead to further investigation and experimenting. Used together, they will help you to gather facts that will increase your knowledge and control of your environment.

Review Questions and Exercises

1. Name four good methods of studying science. Which of these do you consider most important? Why?
2. Experimenting, observing, reading, and inquiring overlap as methods of studying science. Illustrate this statement by an example.

Something to Do

1. Make a ten-minute nature trip into the school yard. When you come back into your classroom, list the names of all the trees and shrubs, flowers and other plants, birds, insects, animals, cloud formations, wind directions, etc., that you observed in the ten minutes. A little friendly competition to see who can make the longest list might add to the fun, but be very certain that you have seen everything listed.
2. Nature science excursions into your own garden are very worth while, at all times and seasons. (In summer, early morning observation tours are especially profitable.) Look for winter buds on trees and shrubs; insects in the grass, on plants and trees; dew on the grass; evidence of soil erosion after heavy rain; germination of seeds; development of flower buds, flowers, fruit, and seeds; earthworms (use a flashlight at night to discover them); listen for bird songs; look for birds feeding, resting, caring for their young. Keep a diary listing your most interesting observations.
3. Plan science excursions to make first-hand observations and secure reliable facts about one or more places of interest, such as a creamery, a grain elevator, a sawmill, an experimental

farm, a prize garden, a town garage, an airport, a weather observation station, or a broadcasting station. Before making the trip, list some things you may see and some of the questions for which you will seek answers. After your return from the visit, share the information you gathered.

4. Tell your class about a trip you have had to some interesting place such as the Rocky Mountains, the Pacific Coast, an experimental farm, a forestry farm, Jasper Park, Eastern Canada, a fox ranch. If possible, use snapshots, pictures, or souvenirs to show your classmates some of the most unusual sights. Briefly state some scientific facts about such wonders of nature as tides, rock formations, geysers, trees, canyons, wild animals, glaciers, waterfalls, etc., that you may have observed.

HOW DO HOBBIES HELP YOUR SCIENCE STUDIES?

You cannot possibly solve all the science problems that are about you; you cannot even read about them all. You will be forced to choose some, and leave others. But which will you choose? Your own interests will be a guide. If there is one particular subject that attracts you, you can make it the centre of your activity. It will be your *hobby*—the work you do for the fun of it. Some hobbies, like collecting rocks, gardening, and watching birds, are a kind of nature study. Other hobbies, building model aeroplanes for example, provide manual training; and a hobby like photography combines workshop and out-of-doors activities. Every hobby suggests a number of related problems, and their solution leads to new interests. Everyone should have a hobby for the pleasure, satisfaction, and relaxation it can bring him.

If your hobby is nature study, you will learn more and more about your environment, and you will find that it grows more interesting all the time. When you make collections of leaves, fruits, bird nests, or wild flowers, you discover that there is endless variety in nature. Building up your collection will provide you with numbers of fascinating problems. If you have an insect collection, for example, you may learn

A pupil's collection of the fruit of trees, shrubs, garden plants, and field crops. Try to identify some of each. Observe the method used to mount and name each specimen.

at first only the names of the different specimens. But you will soon discover that each one has a life-history and habits of its own, and you will want to find the answers to many questions about it. Where does it lay its eggs? What do the young look like? What do they eat? Every good science hobby leads to further reading and investigation, and to new interests.

Gardening is a hobby that offers a good opportunity for you to apply your knowledge of plants, suitable soils, soil foods, and the effect of weather on crops. All the methods of studying science will be helpful. You can observe plants and flowers and the conditions under which they flourish. Read-

These insects were collected and mounted by a pupil in the autumn. The names of some of the specimens which can be seen most distinctly are: 5, monarch butterfly; 7, common white butterfly; 8, tiger swallowtail butterfly; 9, 15, 16, sulphur butterflies; 10, 14, 18, dragon-flies; 12, viceroy butterfly; 17, painted lady butterfly; 21, silver spot butterfly; 22, red admiral butterfly; 23, damsel-fly; 24, banded purple butterfly; 26, mourning cloak butterfly; 31, polyphemus moth; 33, 40, grasshopper; 34, sphinx moth; 36, 38, underwing moths.

ing will keep you informed about new varieties of flowers and new methods of soil culture. You can find solutions to some of your problems by discussing them with experienced gardeners. And you can learn much about gardening by experimenting. If you start your garden with plants that are easy to grow, you will be able to improve it each year, as you make new discoveries. A garden that has been planned artistically and cared for scientifically brings pleasure to all who see it.

Many people have found that the study of birds grows more interesting every year, and is a hobby that they can follow for a lifetime. It is not restricted to one season, but can be enjoyed throughout the year. In the fall, migrants gather in flocks ready for the long journey to their winter feeding grounds. Some birds that have nested during the summer in the far north return with their families. Even people who have learned to identify many birds need to watch these families carefully, because the colour markings of the young birds, or juveniles, are often different from those of their parents. Day by day the migrants leave for the south. But with the cold weather, interest turns to chickadees and other birds that stay with us all winter. Their natural food is often hidden under the snow. Consequently one of the best ways of learning to know and make friends with winter birds is to erect feeding stations where they will gather.

When the first warm spring days come, bird lovers watch eagerly for the return of the migrants from the south, and keep records of the dates they arrive. What a thrill they experience when they see the first robins, or the first flock of Canada geese winging their way north! Sometimes they identify birds that are very rare in their district. They listen to bird notes and often learn to recognize different kinds of warblers by their songs. With the warmer days, nesting begins. Bird lovers never molest a nest or annoy a mother bird. They watch for the hatching of the eggs, and see how the baby birds are fed and how they learn to fly. Later they watch them preparing to make the long trip south in the fall.

Something to Do

If your hobby is studying birds, you and your friends could organize a bird club. Probably someone in your district would be able to help you at first, and to show you how to study birds. You will find the following books helpful: *Birds of Canada* by P. A. Taverner, Musson Book Co.; *Field Guide to the Birds* by R. T. Peterson, Houghton Mifflin Co.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A naturalist who has chosen photography as his hobby has used his camera to record the story of the transformation of a caterpillar into a butterfly. His story of the Monarch Butterfly is told in the pictures on the opposite page and above, as follows: (1) The full-grown milkweed caterpillar ready to pupate. (2) The caterpillar, with its mouth, spins a silken button to the under-side of a leaf or other suitable location. To this button it attaches its tail-end, and then swings head-down. (3) Within a day or two, the skin of the caterpillar splits and falls away. See the leaf below. (4) A few hours later the caterpillar has fully pupated. It remains in the chrysalid stage until it emerges as an adult butterfly, from one to three weeks later. (5) After seventeen days, the chrysalid shown here had darkened. The developing wings of the butterfly can be seen forming within. (6) Without warning, the chrysalid splits, and the emerging butterfly commences to drag itself from its folded position. (7) Within a minute it somersaults out, and its wings begin to expand rapidly. (8) It remains clinging to its chrysalid until the wings have stiffened, when it is ready for flight. (9) The adult butterfly. Note the scent glands (which serve to attract the female) near the centre of the inner wings. Monarch butterflies seem to possess some protective chemistry, for birds and other such enemies usually refuse to touch them. Sometimes during the fall great flocks of these butterflies may be seen migrating south. Whole colonies of them may also be seen resting in trees or even in fields, where they cling to grass, weeds, and other small plants. (Photos by Hugh M. Halliday)

People who are interested in nature often choose photography as a hobby. A camera helps to develop powers of observation, and the search for good subjects for pictures leads to new interests. By studying the methods used to print and enlarge pictures, you may learn a great deal of science. By reading you can keep in touch with new discoveries, like the recent development of colour photography, and so improve your own workmanship.

NOTE.—For helpful hints about photography, consult *How to Make Good Pictures* by Eastman Kodak Co. and *The Fun of Photography* by Mario and Mabel Scacheri, published by Harcourt, Brace & Co.

Review Questions and Exercises

1. Make a list of all the science hobbies you can think of. Which of these have you taken up already? Name some you hope to follow later.
2. Mention a science hobby that interests you, and show how it could increase your knowledge of science.

Something to Do

1. Start a science library in your school. Bring from home old copies of science magazines and books containing interesting stories about scientific discovery and invention. A scrap book containing science clippings from the daily press would also be worth while. With a little co-operation among pupils and an arousing of interest among parents and friends, a valuable addition could be made to your school library in a short time.
2. Try to add books on science hobbies to your library. Write to publishing companies for lists of suitable books.
3. Organize a science museum as a school or community undertaking. Include collections of leaves, insects, bird nests, wild flowers, heads of different varieties of wheat, oats, barley; samples of soil from different parts of the district; fossils, Indian arrow heads, etc. Any specimens related to the study of science could be included. Attach to each specimen a card showing the name of the article, where it was found, the date of finding,


A good beginning for a school museum. It includes collections of leaves, seeds, soils, insects, rocks, and fossils, as well as an aquarium.

the name of the donor, etc. Select a committee of pupils to look after the museum: to receive new specimens; to enter them on permanent lists; and to arrange for space for displaying the exhibit. A good museum is always an important aid to the study of science.

4. Bring to school a collection you have made, and tell your class what you have learned about each item in the collection.

5. Invite to your school someone who has an interesting science hobby, and have him give a talk to your class.

6. During Education Week, or at some other special time, have a display of science hobbies, and invite your parents to the school. Whenever possible, be working at your hobbies. Be prepared to explain the details of the display to your visitors.

7. Arrange a science display for the spring of the year. Display apparatus you have made, and perform experiments using this apparatus. Show collections, charts, note-books, and any other work you have done in your science course. Give reports on science topics you have investigated.

8. In the thirty-one-year period between 1910 and 1941, Western Canada won the award for the best hard spring wheat at the Chicago International Livestock Exposition and Grain Show twenty-seven times. Many prizes for oats, barley, and other farm crops also have been won. Among the Canadian winners there have been many young people who have been closely identified with junior grain clubs. These organizations encourage scientific farming methods. If there is no junior grain club in your district, perhaps you can organize one.

Test on the Scientific Method

1. List, in order, the six steps of the scientific method.

2. Tell in detail how you would use the scientific method in connection with any one of the following: (*a*) buying a new pair of shoes; (*b*) making an insect collection; (*c*) building a model aeroplane; (*d*) making candy; (*e*) growing bulbs for winter bloom.

3. Recently a scientist performed an experiment to discover whether it is better to roast meat at a high or a low temperature. Two rib roasts, one from each side of the same beef animal, and each weighing 18½ pounds, were roasted in the same type of oven. One was roasted at an oven temperature of 300 degrees Fahrenheit, and the other at 500 degrees Fahrenheit. Both were cooked to the same degree of "doneness" as determined by a meat thermometer. Again each was accurately weighed. The roast cooked at 300° F. now weighed 15½ pounds (a loss of 3 pounds), while the roast cooked at 500° F. weighed 12 pounds (a loss of 6½ pounds). Also, the low temperature roast was judged to be more palatable and served five more persons than the one cooked at the high temperature.

(*a*) What was the question or problem for which the scientist sought an answer?

(*b*) What conditions were the same for both roasts?

(*c*) What condition was different?

(*d*) What observations were made?

(*e*) State the conclusion that you think would be justified.

(*f*) Do you think that the conclusion should be subjected to further testing, using roasts of lamb and of pork? Why or why not?

(*g*) Would it be just as satisfactory to use for the test (1) a roast of beef and one of pork, or (2) two rib roasts from different beef animals? Explain fully.

Test your Knowledge

Rewrite the following sentences in your science note-book, using only the words necessary to make a correct statement in each case:

1. Five scientists mentioned in this chapter are: *Pasteur, Banting, Galileo, Leeuwenhoek, Faraday, Marconi, Morse, Priestley, Jenner, Newton.*

2. The first step in the scientific method is *to perform an experiment, to recall past experience, to define the problem clearly.*

3. It can be proven by experiment that air *is present in a vacuum, occupies space, is composed of only one substance.*

4. Because air is a real substance and has weight, it *exerts pressure, is used for the burning of fuels, is necessary for all living things.*

5. The pressure of the air directly above the wing of an aeroplane in flight is *greater than, the same as, less than* the pressure beneath the wing.

6. An experiment is *the same thing as the scientific method, an important step in the scientific method, a means of finding the answer to any question.*

7. In recording an experiment, under the heading "observation" you should state *what you learned, what you did, what you saw.*

8. If something unusual happens, it is more scientific to *look for no explanation, attribute the happening to some superstition, try to find the real cause.*

9. A scientist *never changes his mind, allows his personal opinions to influence his judgment, is open-minded.*

10. A person with a scientific attitude *bases his judgment only on facts, believes everything he hears or reads, makes important decisions without first getting the facts.*

11. If scientists make as many discoveries in the next hundred years as they have in the past hundred, there probably will then be *no, few, many* science problems left to solve.

12. The scientific method can be used *only in the field of science, in solving any problem, by trained scientists only.*

13. Leeuwenhoek was the first to discover *arteries and veins, that bacteria cause disease, microbes.*

14. Marconi invented *the trans-Atlantic cable, wireless telegraphy, the electric telegraph.*

15. Marconi *made little use of the scientific method, tested his ideas by experiment, made no use of the discoveries of other scientists.*

16. To be of real value an experiment *must be carefully planned and painstakingly performed, must be performed only by a trained scientist, must be planned to test at least two factors in each test.*

17. Making first-hand observations is a method of studying science which can be used *only after children are able to read, very little by pupils in school, very widely by children and adults alike.*

18. Science hobbies *are a waste of time, should be undertaken only outside of school, provide an excellent way to become well informed about some branch of science.*

Saskatchewan Tourist Bureau

Should the harvest fail for a single year, famine would depopulate the world.

—INGALLS.

CHAPTER TWO

CHAPTER 2

PLANTS, THE WORLD'S FOOD FACTORIES

If there were no green plants, there would be nothing to eat and little to wear. Even when you drink milk, you are using food made by plants. Why do we say that the leaves are the "workshops" of the plant? How are roots adapted for "pumping" water to every tree and twig? A strong salt solution placed around the roots of a plant will kill it. Why? How can the age of a tree be determined by examining the stump?

The bread we eat, the food in the milk we drink, the cotton, wool, or silk in the clothes we wear, the leather in the shoes that protect our feet, the wood of which our houses are built, the fuel that keeps us warm, the rubber in the tires on which our automobiles run, and even the paper on which this book is printed, all have been created by myriads of little factories that to us are just green plants. Some of these products, such as grain and cotton, come directly from plants in a form in which man can use them. Others, such as milk, wool, and silk, come indirectly from plants, since the plants supply the food for cattle, sheep, and silkworms. Even the fishes of the sea are dependent on green plants. You can readily see, therefore, that it is important to know something about how plants live and work.

PLANTS ARE FACTORIES.

When we wish to produce food, we plant crops, such as wheat, potatoes, or apple trees. The plants that grow become "factories" for the manufacture of food. During the long

summer days, each green plant is busy taking in water from the soil and carbon-dioxide gas from the air, and combining them to form sugar and other foods. All green plants manufacture sugar. We know how sweet a beet can be, or an apple, or a kernel of corn.

If you were to visit a factory, you would find (1) stores of *raw materials*, (2) intricate *machines* in which the raw materials are changed into manufactured goods, (3) a power plant to furnish *energy* to operate the machines, (4) *manufactured goods* ready to be shipped away, and (5) in many cases, *waste products* that cannot be used.

In a plant, operations go on very much as they do in a factory. Raw materials (water and minerals from the soil and carbon-dioxide from the air) are taken in and changed in the "machines" in the plant into manufactured goods, or food. Wastes are thrown away. The manufactured food is transported to other parts of the plant. In this chapter you will discover how these operations are carried out.

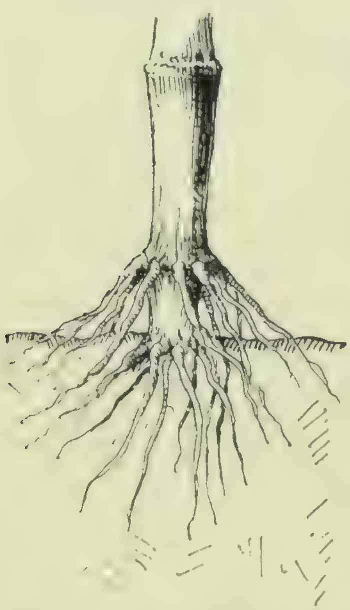
ROOTS AND THEIR WORK

The first operations that take place in the plant factory are performed by the roots. The roots serve the plant in several ways: they anchor the plant in the soil, they absorb food (raw materials) from the soil and carry it upwards to the stem, and in some cases they store reserves of food for the plant to use later in producing flowers and seeds.

If you have tried to pull up by the roots dandelion, clover, or alfalfa plants, you know that such plants are held very firmly in the soil by a main root, which grows directly downward. Such roots may extend many feet down in their search for water. Branching from this primary or main root are many smaller secondary roots. These serve as feeders for the large central root. This type of root system affords a convenient form for food storage, and is typical of plants having stems that die down in the fall and grow up fresh from

the root in the spring. It is called a *tap-root system.* Make a list of all the plants you know that have tap roots.

Fleshy tap roots, such as those of beets, turnips, carrots, and parsnips, are used extensively as food both for people and for cattle, sheep, hogs, and other animals on the farm. A high percentage of the sugar used in this country is manufactured from the sugar beet.



The corn plant has a fibrous root; it also sends out prop roots from the lowest joint or node.

In wheat, corn, grass, onion, and a host of other plants is found a type of root system which differs from the tap root system in that it has no large main root. Instead, it has a great many roots all about the same size, all arising from the base of the stem and extending in many directions through the soil. This is called a *fibrous root system.*

Something to Do

HOME EXERCISE.—Examine the roots of the common field and garden crops and weeds. Classify them as tap root systems and fibrous root systems. Which of the roots are annuals, and which live for more than one year?

To understand how roots absorb food and carry it to the plants, and how they store the reserve food supply, it is necessary to know something of the parts of a root. All roots, whether they are fibrous or tap, large or small, have the same parts. You will find it easier to see the parts, however, if you choose as your specimen for study a large root such as the carrot.

Something to Do

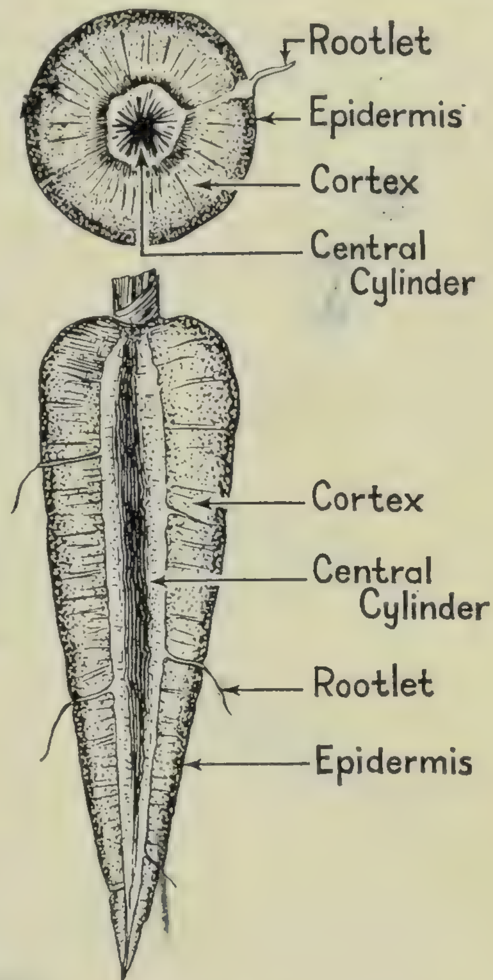
Cut a cross-section of a carrot at the junction of a rootlet, and examine it. The tough outer part is the *epidermis.* It protects the root and helps to keep it from drying out. Observe the orange-coloured, softer area just inside the epidermis. This

is the *cortex* (kōr′tĕks), in which food is stored in the carrot. Find in the centre of the root the *central cylinder*. This part contains the tubes or ducts for transporting sap. How does the central cylinder compare with the cortex in colour, hardness, and taste? Look for *rootlets* in the cross-section. Do they arise from the epidermis, the cortex, or the central cylinder?

Make a drawing of a cross-section. Label all the parts.

Cut a lengthwise section through the middle of the carrot. Identify the parts as you found them in the cross-section, namely epidermis, cortex, central cylinder, and rootlet. Try to separate the central cylinder from the cortex. To which part are the leaves attached?

Draw the lengthwise section, and label it fully.



A cross and a lengthwise section of a carrot. Look for the same parts in other roots.

ROOT HAIRS

Water is very important to the welfare of a plant. If plants do not get water, they soon die. Water helps them to secure food materials from the soil, serves as the liquid for carrying food to and fro, keeps the cells of the plants full and expanded, is used in making sugar in the leaves, and promotes growth in the plants in a number of other ways.

To get into a root, water must be able to pass through the surface cells. As roots become larger and older, the outer cells become cork-like and practically waterproof. Water can then pass into the root only through those surface cells near the tip of the young root or rootlet. To increase the absorbing surface, thousands of cells on the epidermis send

out little tubes called *root hairs.* To learn more about root hairs, plant some seeds and observe them as they germinate.

Something to Do

Put some blotting paper in the bottom of a saucer or of a glass jar. Saturate the paper with water. Place some radish seeds or some wheat kernels on the blotting paper, and cover the saucer with a sheet of glass or with another saucer inverted. Keep in a warm place, and add more water from time to time if necessary in order to keep the seeds moist.

Observe the seeds as they germinate, and examine them closely after three or four days. Notice that the root develops before the shoot. Watch for the early development of root hairs, and see if the roots grow downward and the shoots upward. Locate, near the end of each root, a mass of *root hairs.* Examine them against a dark background with the naked eye, and then observe them closely under a magnifying glass. What do they look like? Where are they most numerous? Are there any at the very end of the root? How far back from the end do they extend? Estimate the number of root hairs on one-tenth inch of the root.

A germinating wheat kernel, showing root hairs.

Make a drawing of a germinated seed, showing shoot, root, and root hairs. Whenever possible, you should use as a model a specimen of your own.

Root hairs are usually found in great numbers on all soil roots. They are extremely slender, closed tubes with frail walls. They are filled with cell sap. A root hair never grows to be a root. As the rootlet increases in length, new root hairs develop near the tip, and those farther back wither and die. The root hairs push in between the tiny soil particles and so come in close contact with the water that clings as a thin film around the grains of soil. Thus the absorbing

surface of a root system is increased from twelve to fifty times, according to the variety of the plant of which it forms a part.

HOW DOES WATER GET INTO THE ROOTS OF PLANTS?

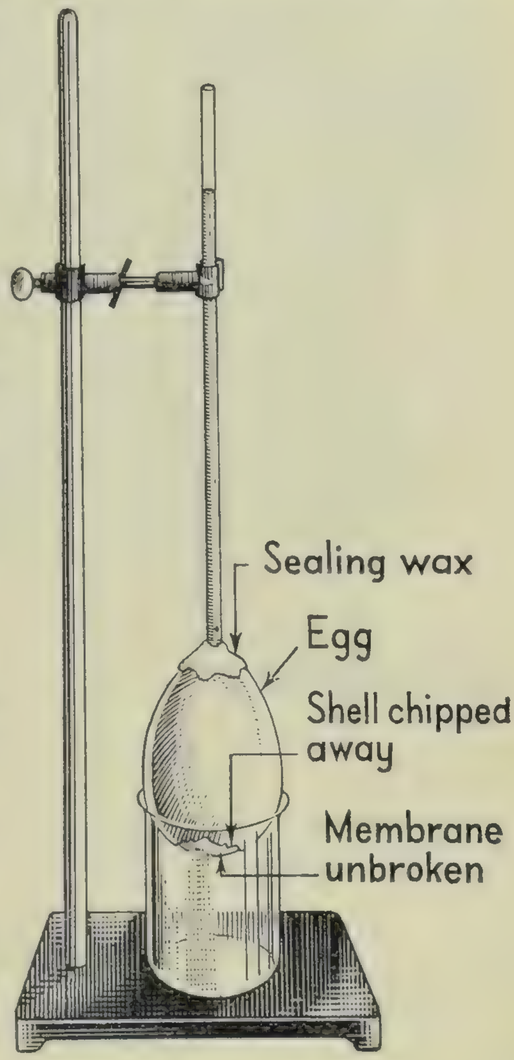
This question can best be answered by setting up an experiment in which the conditions closely correspond to those that prevail when roots absorb water from the soil.

Something to Do

Problem.—What happens when a strong solution is separated from a weak solution by a plant or animal membrane?

NOTE.—Solutions are formed when one substance dissolves in another; for example, sugar in water, or salt in water.

Apparatus and Material.—A hen's egg; a glass tube about five-eighths of an inch in diameter and a foot in length; a glass bottle in the mouth of which the egg will rest; sealing wax.

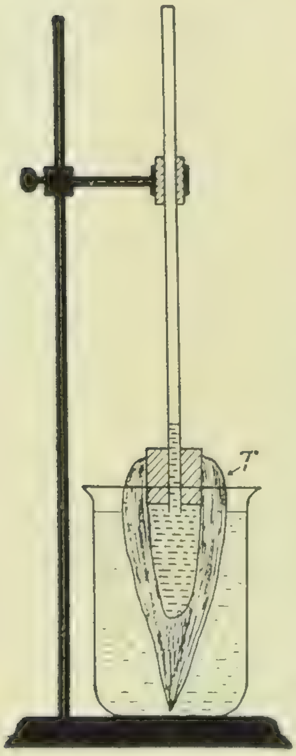


An experiment to illustrate osmosis.

Method.—Very carefully chip the shell off the large end of the egg until an area about the size of a fifty-cent piece is uncovered. Do not break the membrane that lines the shell. At the small end, chip a *small* hole through the shell. This should be just large enough to accommodate the glass tube. Puncture the membrane at this end, and also the yolk, using a small knife-blade or needle. Insert the glass tube a short distance (about half an inch) through this hole. Seal the tube to the shell with sealing wax. Make sure that the hole that surrounded the tube has been completely

closed by the wax. Fill the glass bottle with water, and then place the egg in the neck of the bottle so that the exposed membrane is well under the surface of the water.

Observe the progress of the experiment at short intervals for several hours. Keep in mind the fact that the contents of the egg form a strong solution, that the water in the bottle is a weak solution, and that the two solutions are separated by an animal membrane—the thin layer of tissue that lines the shell.



Another way to demonstrate osmosis. Bore a hole in a good-sized carrot, fresh from the garden, and fill the hole with molasses. Insert a glass tube into a one-holed rubber stopper and fit the stopper into the hole in the carrot. Be sure to bind the carrot tightly to the stopper at the point marked T in the diagram.

Observation.—Does any of the egg material rise up in the glass tube? If so, where does the additional liquid come from? State your proof. Does any of the egg material pass out through the membrane into the water? In which direction is the flow greater, into the egg or out of it? How do you know?

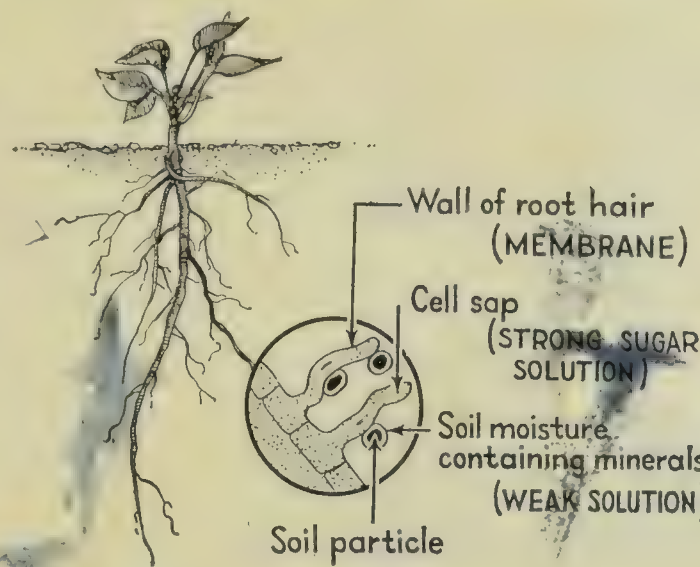
Conclusion.—From the observations you have made, what do you conclude happens when a strong solution is separated from a weak solution by a plant or animal membrane?

Application.—Use the knowledge you have gained from this experiment to find out how roots obtain water and minerals from the soil.

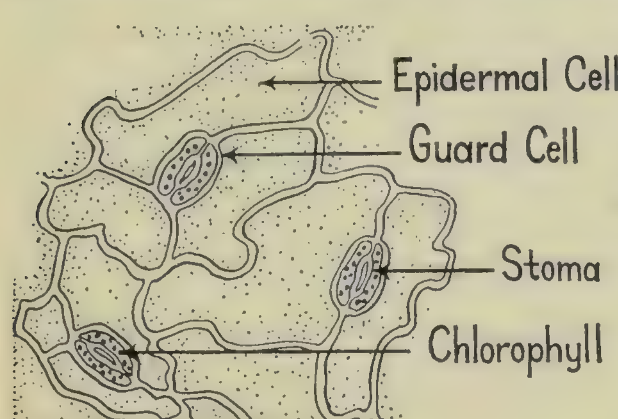
ALTERNATIVE EXPERIMENT.—Soak several dried raisins in water for two or three days. Change the water at intervals. Why do the raisins swell up? This is another example of the exchange of solutions through a membrane.

When two solutions of different strengths are separated by a plant or animal membrane, the weaker solution passes through the membrane and mixes with the stronger solution. This process is called osmosis (ŏs-mō′sĭs). There is also a flow from the stronger to the weaker solution, but this movement is not so rapid.

Soil water enters the roots in the same way as the water passed into the thick egg solution in the foregoing experiment. The soil water containing dissolved minerals is the *weak solution.* It forms thin films around the soil particles. The root hairs push in between the soil particles and come in touch with the film moisture. The cell wall of the root hair is the *membrane* through which the soil water passes. In each root hair there is cell sap, which is a *strong sugar solution.* So we see that a weak solution (soil water) is separated from a strong solution (sap) by a plant membrane (cell walls). The result is that the soil water passes from the soil into the root hairs. From the root hairs it moves from cell to cell and finally reaches the tubes in the central cylinder, through which it is transported to the stem and the leaves.



A diagram to illustrate how roots secure water and minerals from the soil. A part near the tip of a branch has been magnified to show a few root hairs.



A small piece of the lower epidermis of a leaf, greatly enlarged. Note the tiny openings, or stomata. Each opening is called a stoma.

Review Questions and Exercises

1. Name the parts of a root. State a function (use) of each part.

2. Describe a root hair. Where are root hairs found? What purpose do they serve?

3. Compare a root hair with a root under the following headings: *structure, purpose, length of life.*

4. Describe an experiment to illustrate osmosis. Write your description under the usual headings. Make a labelled drawing of the apparatus used.

5. How does soil water get into a plant? Explain the process as fully as you can.

6. Alkali soils contain a very large amount of soluble salts; as a result, the water in these soils is a stronger solution than the cell sap of a plant. Plants do not thrive in such soils. Apply the knowledge you have gained about osmosis to explain this.

It frequently happens that plants take in more moisture than they require. The surplus is *transpired* (given off) through tiny openings in the leaves. Investigate this by inserting a few leaves of a plant into a small, *dry*, clean bottle arranged as in the diagram. Plug the mouth of the bottle with cotton batting. Place the plant in a warm window. Watch for the appearance of moisture on the inside of the bottle.

THE TRANSPORTATION SYSTEM OF A PLANT

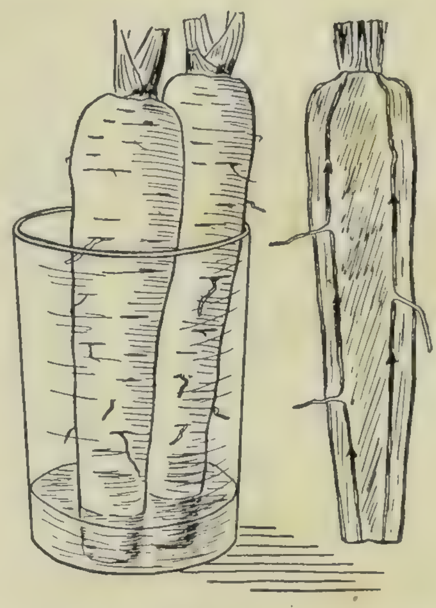
When raw materials have been brought into a factory, they must be taken to the place where they will be turned into the manufactured product, and the product must then be taken to the place where it is to be used. In plants, the soil water taken in by the roots must be taken to the leaves, and the food made in the leaves must be carried down to nourish or be stored in the stems or roots. The transportation system of a plant runs from the root hairs to the tips of the leaves.

To find the path by which water travels upward through the root, perform the following experiment.

Something to Do

Cut the lower ends from two parsnip roots, *fresh from the garden.* Let the roots stand overnight with the cut ends in about half an inch of diluted red ink. Cut a cross-section from one and a lengthwise section from the other. Where do you find traces of the red ink? Where, then, must the up-tubes in the root be located? From the observations you have made, what conclusion do you reach regarding the part of the root through which the soil water rises?

Make drawings to indicate the exact position of the tubes.



Parsnip roots standing in red ink. Find the part of the root in which soil water rises.

One of the functions of roots, as illustrated in the foregoing experiment, is to transport soil water containing dissolved mineral material upward to the stem. The tubes, or water ducts, that render this important service to the plant are situated in the outer part of the central cylinder. The tubes that carry the food downward from the leaves are in the same region of the root. These up-tubes and down-tubes in the root are grouped together in bundles called *vascular* (văs′kū-lar) *bundles.*

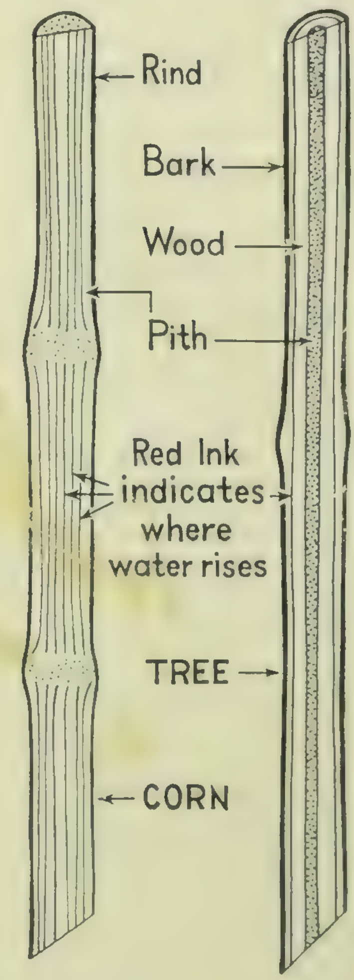
The stem forms the connecting link between the roots and the leaves of a plant. It too has a set of tubes through which the flow is upward to the leaves, and another through which the flow is downward. Where are the vascular bundles found in stems?

Something to Do

1. Stand *freshly cut* twigs of poplar, Manitoba maple, and geranium in diluted red ink for a few hours. Then use a sharp knife to make a cross-section and a lengthwise section of each

twig. Where has the red ink risen? Where, then, are the tubes located that carry water upward through these stems? The up-tubes of the bundles lie immediately under the inner bark,

An experiment to show the rise of water in stems. A corn stem and a tree stem are shown standing in diluted red ink.



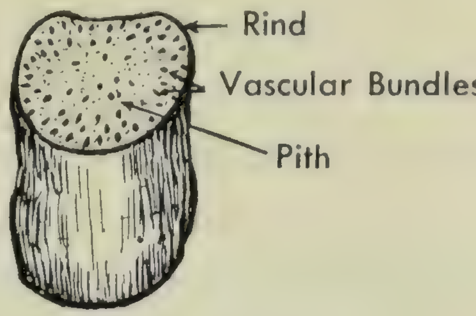
A drawing to show the part of stems in which water rises.

while the down-tubes are located in the inner bark. How are these bundles of tubes arranged?

2. Make cross-sections and lengthwise sections of corn stems, and examine them closely. Filling the stem is a light, spongy material called *pith*. Observe the fibres that run through the pith. These are the vascular bundles. Are they arranged in a ring, or are they scattered?

Next, stand a *freshly cut* corn stem in diluted red ink, and see if the ink rises in the vascular bundles.

Make labelled drawings to show what you observed in these experiments.



A piece of corn stalk.

In the leaf, the transportation system is provided by the veins, which also form the skeleton and give the leaf its shape. There are two kinds of veining, as you can discover for yourself by examining a variety of leaves.

Something to Do

1. Observe the veins of leaves of the poplar, Manitoba maple, and nasturtium. Notice that they are much branched and that they run into one another to form a fine network. Such leaves are *netted-veined.* Next, examine leaves of corn, wheat, grasses, and lily. Observe that each of these leaves has many veins about equal in size running side by side from the base to the tip. These leaves are easily torn lengthwise. Try to tear one. They are *parallel-veined.* The veins in the leaves connect with the vascular bundles in the stems.

A simple, netted-veined leaf. Notice how the veins form a skeleton for the leaf.

2. Select a celery stalk bearing leaves. Cut about one inch from the base, and stand the stalk in diluted red ink for several hours. Examine the leaves for the presence of red ink. Cut cross-sections of the stalk, and note the parts through which the ink has been rising.

Your studies will have shown you that the transportation systems of plants include parts of the roots, stems, and leaves.

HOW CAN THE AGE OF A TREE BE DISCOVERED?

The growth that takes place in the stem of a tree produces variations in the wood from which it is possible to determine accurately the age of the tree.

Grass leaves are parallel-veined.

Something to Do

Obtain a number of cross-sections of tree stems—blocks of wood will do. The ends should be made smooth with a plane if one is available. Notice that there are circles of wood radiating out from the centre. These are known as *annual rings*. One of these rings of wood is added to the stem each year; hence the age of a tree can be determined by counting the number of annual rings.

How old are the trees from which your specimens were obtained? Are the rings uniformly spaced? How do you account for any differences noted?

In the spring, in order to produce a new crop of leaves, a tree must quickly raise vast quantities of food-laden sap to the farthest tips of all its twigs. Later in the season, growth and the circulation of sap are not so rapid. Consequently the structure of the wood formed at the beginning of the growing season is very different from that of the wood formed at the end. The wood formed in the spring has comparatively large tubes, well adapted for rapid upward movement of sap, and is therefore softer and more porous than the wood formed later in the season, when growth and circulation have slowed down.

Though this change is gradual and not very marked during one growing season, the difference between the new, soft spring growth of one year and the last and hardest wood of the year before is sufficient to produce a line where the woods join.

The end of a pine log showing the layers of wood added each year. How many years did it take this tree to grow? (U.S. Forest Service photo)

26 yrs.

Because such a line is formed each year, and because it completely encircles the stem, it is called an "annual ring." From the annual rings it is possible not only to determine the age of a tree, but also, by comparing their widths, to learn much about climatic conditions during the past.

If you go into the autumn woods with your eyes and ears open, you will learn many interesting things about the plants and animals that live there. (Soil Conservation Service photo)

A RAMBLE THROUGH THE AUTUMN WOODS

Take advantage of a warm, bright afternoon in late September to go on a hike to the woods or fields. If you go with your eyes open, you will find a wealth of beautiful and interesting things to observe and study. On every hand you will see a riot of colour—bright yellows, flaming reds, vivid oranges, and rich browns, mingled with all shades of green,—the whole beautiful picture framed by the great arch of the blue autumn sky.

The plants have almost finished their work. Some weeks ago, the poplars, the choke-cherries, and other trees and shrubs began to prepare for winter. Their summer activities gradually ceased. All valuable food supplies in the leaves were withdrawn to other parts. A waterproof layer of cells was formed between the end of each leaf stalk and the branch to which it was attached; then the leaves were ready to fall

Some leaves you can easily identify. In this illustration are shown: in the top row, elm, cottonwood, aspen, poplar, and birch; and in the bottom row, spruce, Manitoba maple, chokecherry, and green ash.

from the trees, either by their own weight or with the help of a push from the hurrying winds. As autumn approached, the green colour disappeared from the leaves, and other colours have now taken their place. These rich autumn colours are produced by substances that the leaves have been accumulating all summer from the water that passed through them.

Something to Do

1. While on your hike, carefully select well-formed specimens for a collection of common leaves. Do not include conifers (pine, spruce, etc.). Carefully press your leaves, and mount them in a drawing book or a book of your own design. Arrange your specimens in groups according to the kind—that is, group the leaves of the different varieties of poplars on the same page. Do the same thing with the willows, maples, spirea, etc. Print the name of each leaf neatly beside it

Suggestions for pressing leaves.—To retain their natural colours, leaves must be dried and pressed *quickly*. Fold sheets of newspapers to make *driers*, using from six to eight ply of paper. Place a number of leaves in each drier. Insert the driers into pages of several magazines, and press them between two flat surfaces. Once a day for several days turn the driers inside out,

or change them entirely, each time exposing the leaves to the air for a few minutes.

The leaf outlines on page 55 will help you to identify your leaf specimens.

2. Observe how the trees, shrubs, and other plants around you are "closing up their factories" for the winter. They will not reopen until the spring. Why?

Review Questions and Exercises

1. What are vascular bundles? How are they arranged in (*a*) tree stems, (*b*) corn stems?

2. Describe an experiment to show where water rises in a tree stem. Use the usual headings: *Problem, Apparatus and Material, Method, Observation,* and *Conclusion.* Illustrate the experiment with a drawing.

3. What are annual rings, and how are they formed?

4. How is it possible to determine accurately the age of a twig of a tree?

5. Describe two types of arrangement of veins in leaves. State two functions of the veins.

6. Describe an experiment to learn through which part of a root soil water rises.

7. Why is the transportation system of the roots, stems, and leaves an important part of the plant "factory"?

8. Describe an experiment to demonstrate that leaves give off water.

OF WHAT ARE STARCH AND SUGAR COMPOSED?

Two of the chief foods that are made by leaves are starch and sugar. These are a source of energy for the plant itself and also supply man with much of his food.

Something to Do

Place a teaspoonful of sugar in a test-tube or a long, narrow bottle. Heat the lower end of the test-tube in an alcohol lamp. Note that drops of water collect on the upper part of the test-tube. This water has been formed from the sugar. The black sub-

stance that remains is *carbon*. Assuming that water is composed of *hydrogen* and *oxygen*, what is the composition of sugar?

Because they are composed of carbon, hydrogen, and oxygen, starch and sugar are classed as *carbohydrates*.

HOW CAN WE TEST FOR THE PRESENCE OF STARCH?

Something to Do

1. Put a few grains of corn starch in a test-tube, cover it with water, and shake it well. Dilute some iodine solution with twice its own volume of water. Add a few drops of this weakened iodine solution to the test-tube. What colour change do you observe? If you do not get a blue colour, repeat the experiment, using less starch, or more water, or less iodine solution.

2. In the same way, test the following substances to see if they contain starch: sugar, salt, potato, flour, meat, and pie-crust. Which of the substances contain starch, and which do not? How do you know?

Starch is the only substance that will turn blue when it comes in contact with iodine solution. Sometimes this colour is not pure blue, but is more of a purple or a purplish black.

This test is known as the *iodine test for starch*. You should remember how it is made, as you will need to use it later.

CARBOHYDRATES ARE MANUFACTURED IN GREEN LEAVES.

The three simple substances that compose carbohydrates —carbon, hydrogen, and oxygen—are put together in leaves to form sugar and starch. Where do leaves get carbon, hydrogen, and oxygen? Carbon is present in carbon-dioxide, one of the gases of the air. When leaves are making food, they "breathe" in large amounts of carbon-dioxide from the air. Water is composed of hydrogen and oxygen. As we have seen, water is taken in through the roots and passed up to the leaves. These two materials—carbon-dioxide and water—are united in the leaf to form carbohydrates. This process results in the production of an excess of oxygen, which is given off through the stomata.

The work of making carbohydrates in green plants is known as *photosynthesis* (fō′tō-sĭn′the-sĭs). Photosynthesis means "to put together by means of light."

From the substances obtained from soil water and air, the plant first manufactures *sugar*. Then some of the sugar is usually changed to *starch*, because starch is a more suitable form in which to store food temporarily in the leaf.

Leaves are the food factories of the world.

Most boys and girls have helped to make a kite, a playhouse, a model aeroplane, a doll's house, or perhaps a cake. For the construction of each of these, certain materials are required, and considerable *work* must be done to assemble the raw materials into the finished product. To build a playhouse, for example, one must saw boards and drive nails. This requires the expenditure of considerable *energy* on the part of the builder. By energy we mean the *ability to do work*.

Similarly, work must be done to put carbon-dioxide and water together in the leaves of plants to make carbohydrates. Where do leaves get the energy to do this work. Sunlight is a form of energy. In leaves there is a green substance called *chlorophyll* (klō′rō-fĭl) or leaf green, which has the ability to absorb sunlight, and the energy thus secured is put to work on the raw materials, carbon-dioxide and water, to build them into sugar and starch. Thus the sun's energy is stored up in sugar and starch, to be used later by plant and animal life. This is a wonderful process, the secret of which man has never discovered.

Something to Do

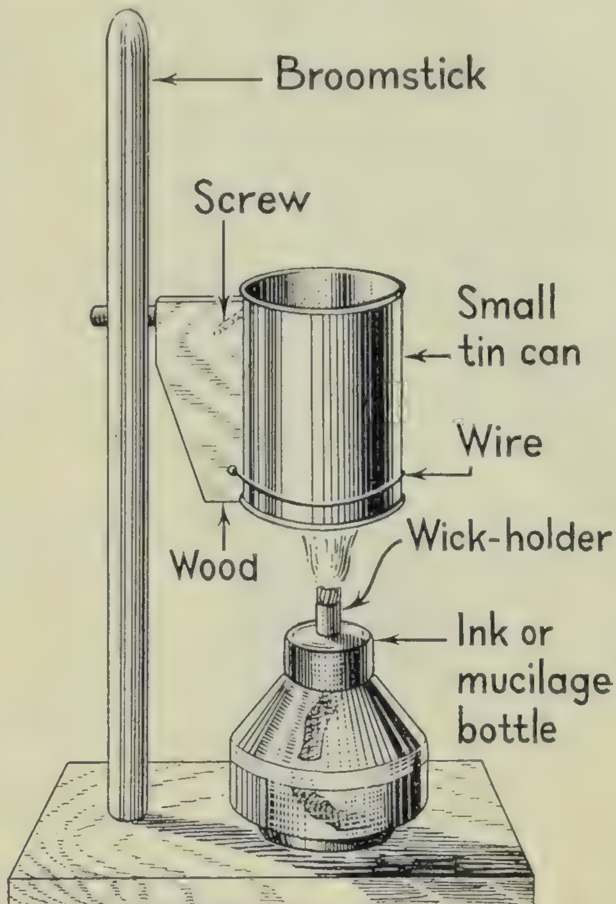
Problem.—Is light essential for the manufacture of carbohydrates by plants?

NOTE.—This experiment should be demonstrated by the teacher. It will be more successful if performed in the afternoon of a bright sunny day during the fall or the spring term. Be very cautious in handling the alcohol—it is inflammable.

Apparatus and Material.—A beaker filled to a depth of about one inch with water; wood alcohol (methyl alcohol); an iron stand; a ring and clamp; wire gauze; an alcohol lamp; pins or paper clips; strips of fairly thick black paper, or black cloth; an evaporating dish; a saucer; iodine solution; a geranium or other green plant.

Method.—By means of paper clips fasten strips of black paper above and below a leaf of the plant in such a way that they completely shut off the light from one-half of the leaf. Set the plant in the bright sunlight.

After at least one day has elapsed, continue the experiment. Support the beaker by means of the wire gauze, the ring, and the iron stand. Heat the water to boiling. Remove the leaf from the plant, and make



A useful home-made substitute for the apparatus required for this experiment. A few pieces of board, a broomstick, a small tin can, and a mucilage or ink bottle are the chief requirements. The wick-holder is a one-inch length of the metal handle of a mucilage brush. A small round wick may be purchased, or a few strands of soft woolly string may be used. The wick should fit through the wick-holder rather loosely. To secure a larger flame, pull the wick a little farther through the holder and loosen it slightly. A cover, such as an inverted tumbler, is useful on the lamp to prevent the alcohol from evaporating. A thin saucer or fruit dish will serve for an evaporating dish.

a drawing to show the location of the black paper. Take the paper off the leaf. Immerse the leaf in boiling water for one minute, or until it is wilted. Then place the leaf in the evaporating dish, and cover it with wood alcohol. Set the evaporating dish in the top of the beaker.

Caution.—Be very careful not to spill any alcohol over the flame, because alcohol is very inflammable.

Keep the water in the beaker boiling vigorously so that the steam heats the evaporating dish and boils the alcohol. Keep the leaf in the boiling alcohol for from ten to fifteen minutes,

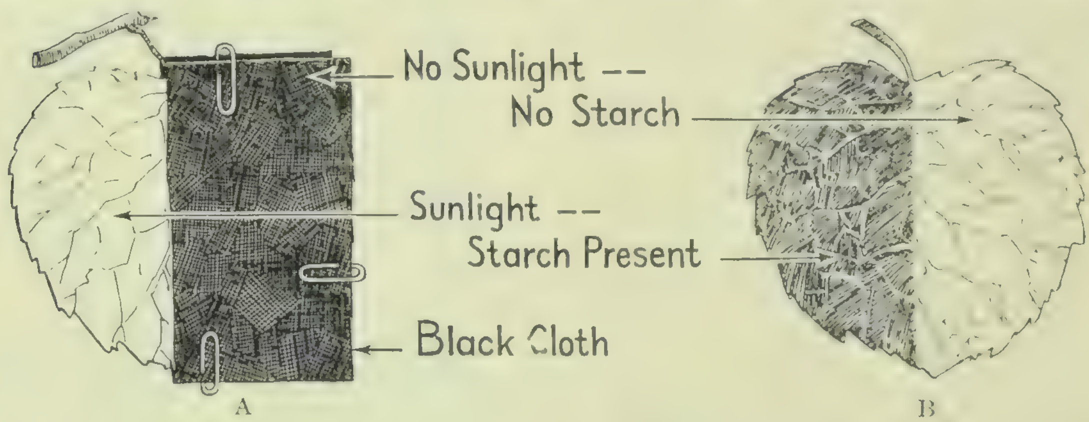


Figure A shows the leaf as it appeared on the plant. Figure B shows the same leaf after it had been removed from the plant, the black cloth taken off, the chlorophyll taken out by alcohol, and the leaf then dipped in iodine solution.

or until the leaf is practically white. It may be necessary to replenish the alcohol. Wash the leaf in luke-warm water. Then spread it out in the saucer, and cover it with iodine solution; allow it to remain in the solution for five minutes or more.

Observation.—(1) Did the part of the leaf that was exposed to the sunlight turn blue or purple? (2) Did the part of the leaf that was covered by the black paper turn blue? The black paper shut off the sunlight from this half of the leaf.

Conclusion.—Which part of the leaf gave a test for starch? Is light necessary in order that plants may produce carbohydrates? What makes you think so?

Make another drawing of the leaf to show your results.

ALTERNATIVE EXPERIMENTS.—1. Is light essential in the process by which plants make carbohydrates? Place a plant in a dark

cupboard for about two days. Place a second plant of the same kind where it will be exposed to strong sunlight. Following the method outlined for the preceding experiment, test for starch a leaf from each plant. What is your conclusion?

2. Is chlorophyll necessary for photosynthesis? Test for starch a leaf from a variegated (green and white) geranium or a foliage plant that has been exposed to bright sunlight. Does the part of the leaf that contained no chlorophyll give a test for starch? Is chlorophyll essential for starch-making? Give reasons for your answer.

The leaves of these huge trees, grown on Vancouver Island, have manufactured a large amount of food to produce the wood and other materials that have been used in their growth. (British Columbia Government Travel Bureau photo)

3. To learn how plants reach for sunlight, set a potted plant in a sunny window. After a couple of days observe the position of the leaves. Turn the plant around, and a day or two later observe the leaves again. Do you notice any change in their position?

4. To learn how sunlight affects the production of chlorophyll in plants:

(*a*) Germinate some seeds, keeping in complete darkness all parts of the seedlings that develop. Observe the colour after several days. Then place the seedlings in the light, and see what happens.

(*b*) Observe potato tubers that have been sprouting in the dark. Place one or two in the light. Observe them daily for several days. What changes take place in the colour and development of the sprouts?

(*c*) Place a board over a small patch of green grass in the lawn. Raise the board from time to time, and notice the colour of the grass.

PHOTOSYNTHESIS IS A MANUFACTURING PROCESS.

Photosynthesis may be compared with a manufacturing process, as you will realize if you study the following table setting forth the chief points of resemblance.

COMPARISON	FURNITURE MANUFACTURING	PHOTOSYNTHESIS
1. Place	factory	leaf
2. Raw material	lumber, screwnails, varnish	carbon-dioxide and water
3. Machinery	saw, plane, etc.	chlorophyll
4. Power	electricity or steam	sunlight
5. Product	tables, chairs, etc.	carbohydrates
6. By-product	shavings, sawdust	oxygen
7. Working hours	8 a.m. to 6 p.m.	daylight

WHAT DOES A PLANT DO WITH THE CARBOHYDRATES IT MAKES?

Some of the carbohydrates manufactured in the leaf are transported by the sap to the various parts of the plant, where they are used in different ways. Some are used to build up new cells and other materials necessary for the growth of the plant. Others are stored away in the root, stem, leaf, or seed for future use. It is important to remember that the energy of light is stored away in the food materials not used up immediately by the plant.

Biennial plants, such as the parsnip and the carrot, store large reserves of food in their roots during the first year of their growth. The food is stored chiefly in the form of starch for use the following year in the production of flowers and seeds. Many perennials, such as trees, also have roots that are capable of storing food. Roots of annuals, such as wheat, for example, are not adapted for storing food.

This tuberous root of the dahlia has a large supply of food stored in it.

Something to Do

Cut cross-sections of parsnips, carrots, turnips, or other fleshy roots. Pour weak iodine solution over the cross-sections. Which part turns blue? Which part remains unchanged? Where, then, is starch stored in these roots?

Make a drawing to show the result you obtained.

In the maple woods at sugaring time. Man makes extensive use of the food supplies that plants manufacture. (Canadian Pacific Railway photo)

Many plants store in their stems reserves of food, which they can either draw upon themselves or use in their reproduction. The sugar cane, for instance, accumulates such large supplies of sugar in its stem that the plant is cultivated for the sugar it affords. Asparagus tips, which are but stems of asparagus, and maple syrup —condensed sap of the sugar maple—also are examples of delicacies that plants provide by their habit of storing surplus food in their stems.

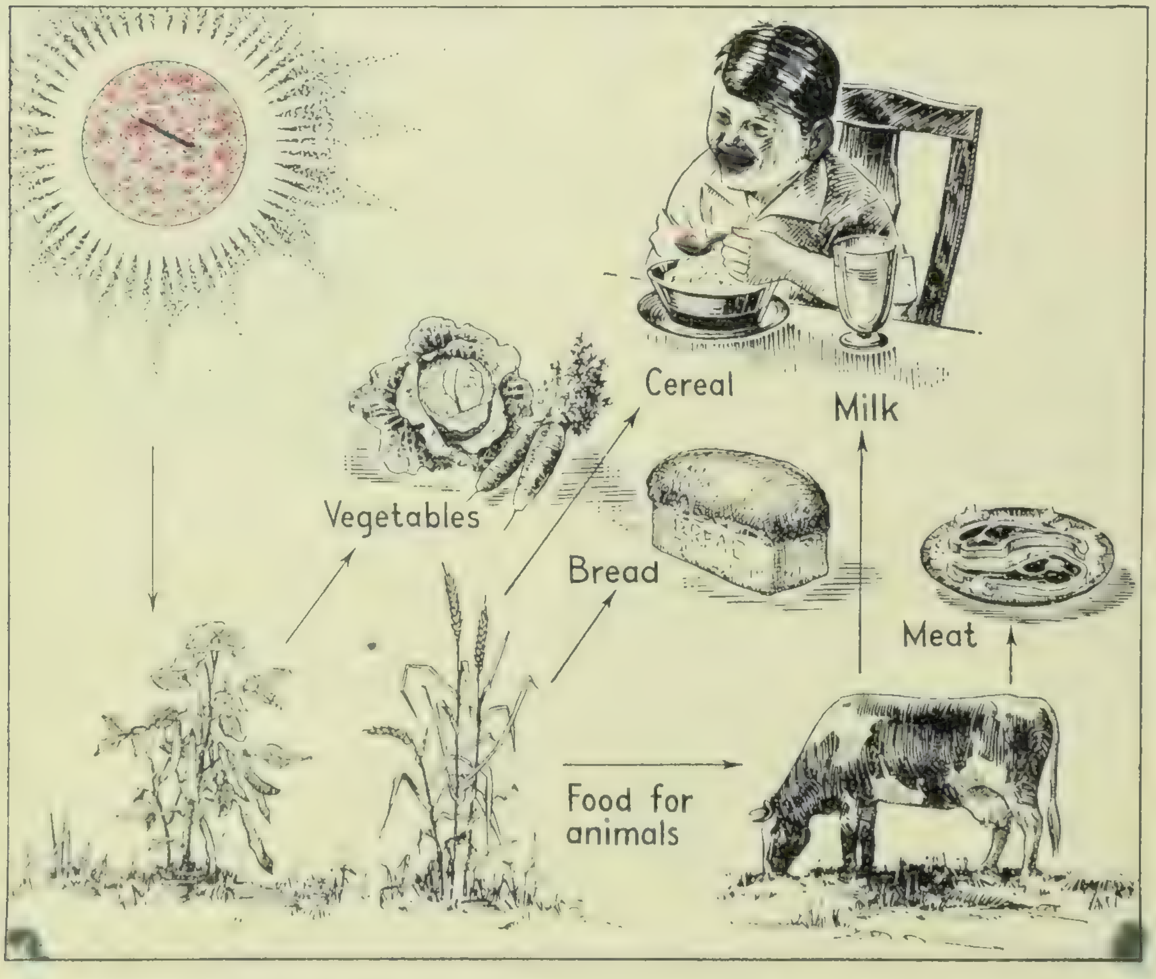
The common potato is perhaps one of the best-known examples of stems that are especially adapted for food storage. This tuber, often incorrectly regarded as a root, is a highly specialized underground stem, carrying generous food reserves for reproduction.

Something to Do

1. Examine a potato tuber to discover the buds, or eyes. Then place the potato in a window where it will receive warmth from the sun, and observe it from time to time as the buds develop into stems.

When you are digging potatoes, observe how the tubers are attached to the main stem of the plant.

2. Test a thin slice of potato with weak iodine solution. Does the potato turn bluish purple or black? Is starch present? If so, where did it come from? Why does a potato plant store starch in its tubers? Of what use are potatoes in our daily diet?



Plants produce all of the world's food supply, using the sun's energy in the process. Animals, however, cannot make their own food. They secure their energy by eating plants or by eating animals that have fed upon plants. Animals are therefore dependent upon plants, and all life is dependent upon sunlight. Show that, regardless of the food he eats, the boy in the above illustration is obtaining his energy from the sun.

Review Questions and Exercises

1. What are carbohydrates? Name two. Of what are carbohydrates composed?

2. Describe a test for starch.

3. Describe fully the process of photosynthesis or carbohydrate manufacture, using the following questions as a guide:

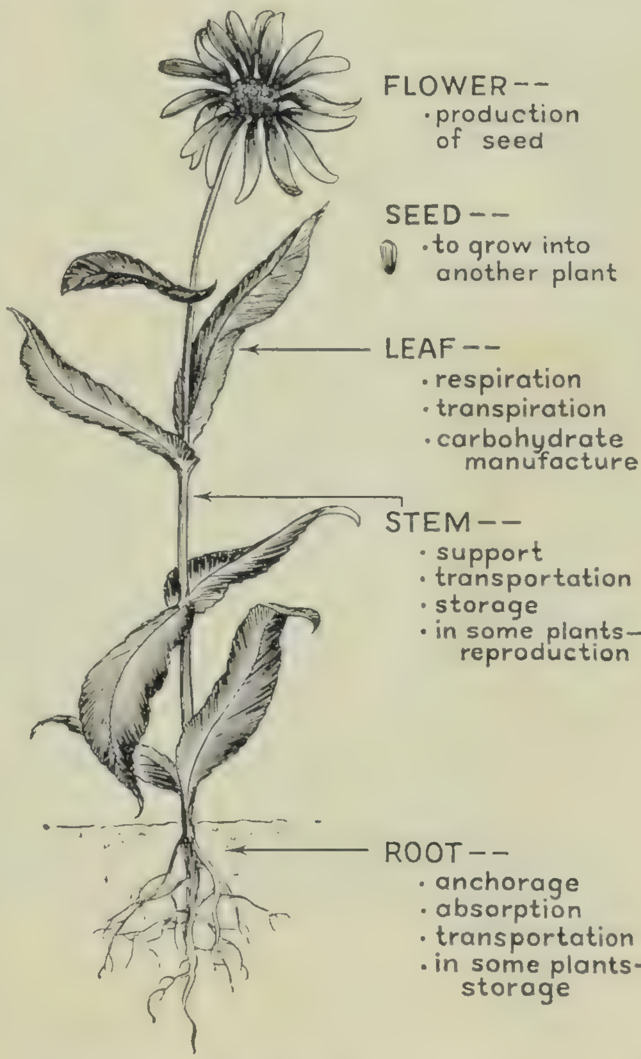
(*a*) What raw materials are used? (*b*) Where does the plant get these raw materials? (*c*) Where and when is the process carried on? (*d*) What is the source of the energy used to do work? (*e*) Why is leaf green or chlorophyll necessary? (*f*) What products are made? (*g*) What is the by-product, and what becomes of it?

4. Describe an experiment to show that sunlight is necessary to enable leaves to manufacture food. Illustrate with drawings.

5. How do plants use the carbohydrates they manufacture? Discuss storage of food in stems and roots of plants.

6. Show that we depend for our food either directly or indirectly upon foods that plants make.

7. The energy that a boy uses when he plays a game of football comes from the sun. Is this statement true? Explain.



Use this drawing to test your knowledge of the life processes of a plant. Each label should have a meaning for you. Explain in your own words the story of how a plant lives and grows.

Test your Knowledge

A. Rewrite each of the following sentences in your science note-book, filling in the blanks with the words that correctly complete the statement in each case:

1. Plants may be compared to ______ because they manufacture food.

2. As a root grows older, the outer cells become practically ______. Soil water is absorbed through the ______ ______.

3. The ______ and ______ of stems of plants are grouped in vascular ______.

4. The age of a tree can be determined by counting the ______ ______.

5. Starch and ______ are composed of carbon, ______, and ______.

6. Green leaves manufacture carbohydrates, using ______ absorbed from sunlight by the ______.

7. The potato is an underground ______, and an iodine test will show that it contains ______.

8. All animals are ______ upon sunlight because they cannot manufacture ______ as plants do.

B. Write the numbers from 1 to 16 in two columns in your science note-book, and after each number write the word *true* or the word *false* to indicate which of the following sentences are true and which are false:

1. Grass leaves are parallel-veined.
2. Water is transpired through the leaves.
3. A root hair grows to be a root.
4. Iodine solution turns starch blue.
5. Leaves can manufacture food in the dark.
6. Starch is made up of chlorophyll and sunlight.
7. Wheat plants have fibrous roots.
8. By *energy* we mean the ability to do work.
9. Chlorophyll is necessary for the manufacture of carbohydrates.
10. Biennial roots do not store starch.
11. Photosynthesis is carried on by animals.
12. All animals depend upon the process of photosynthesis for food.
13. Veins form the transportation system of leaves.
14. Osmosis is evaporation of water through leaves.
15. The raw materials required for the manufacture of carbohydrates are water and carbon-dioxide.
16. All green plants manufacture sugar.

J. Horace McFarland Co.

If there are tongues in trees, and books in running brooks, so surely are flowers the teachers of happiness, joy, and peace.

—SELECTED.

CHAPTER THREE

CHAPTER 3

FALL AND WINTER ACTIVITIES WITH PLANTS

What preparation does a garden need for winter? Perennial flower-beds and sometimes lawns require a "blanket" to protect them from the cold. What materials should be used to make the blanket? How can you have a window full of bloom in January? Do you know how to grow a bulb or start a slip?

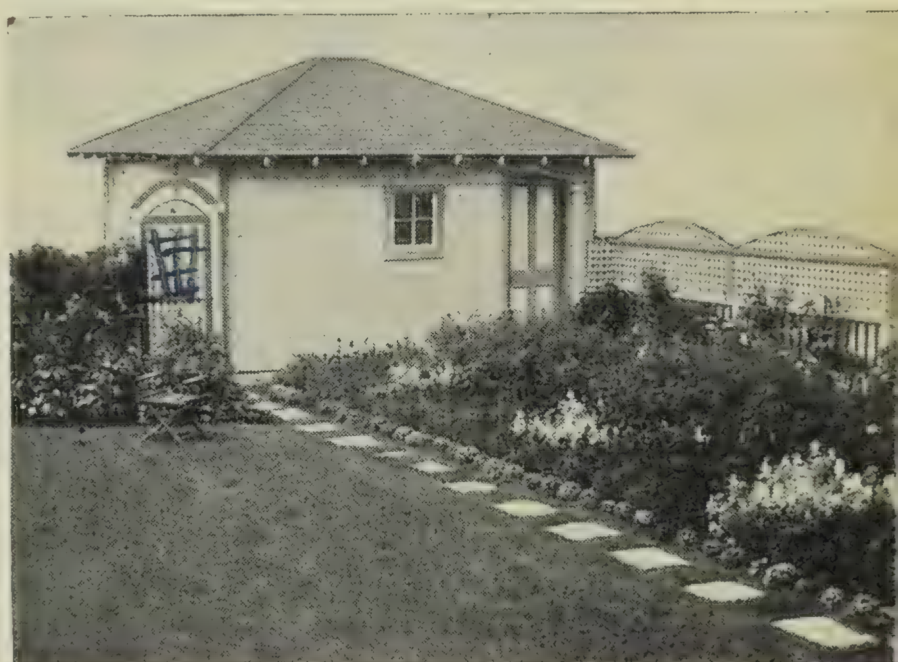
Many people go to the ends of the earth to find enjoyment, while others find it in their own back yards. A gardener knows where to dig for happiness. He finds his chief satisfaction in well-trimmed lawns, in colourful flower-beds, in graceful trees and shrubs, and in row upon row of healthy fruits and vegetables.

If you have never experienced the thrill of seeing plants you have tended and cared for grow into things of beauty or of practical use, plan this fall to give yourself that pleasure by having a garden next year. If you already have a garden, it is not too soon to consider improvements you can make in it. Spend some of your leisure time during the fall and winter months examining seed catalogues, nursery pamphlets, and gardening magazines to find suggestions for making or improving your garden.

The gardener's task is never finished; his practised eye can always find some way of obtaining better results. As every successful gardener knows, fall preparations are just as important and must be just as carefully carried out as spring garden work.

MAKING THE GARDEN READY FOR WINTER

Fall is the time to transplant certain perennials, such as peonies and iris, which you may wish to rearrange in your garden. Dahlia tubers, tuberous rooted begonias, and gladioli bulbs must be stored indoors during the winter. The dahlia roots should be kept in a cool, dark place. The tubers should be spread on a layer of slightly moist sand in the bottom of a box, and covered first with more sand, then with a layer of newspapers. Gladioli bulbs keep well if they are hung up in paper sacks in a cool place.



What will have to be done to prepare this garden for winter?

To reduce the danger of attack by harmful insects, the garden should be kept free of weeds in the fall.

All waste material, such as potato tops and sweet pea vines, should be gathered up and removed. These tops may be used on perennial flower-beds to help to catch the snow; or they may be piled up with alternate layers of soil so that they will rot and form a supply of compost or rich decayed vegetable material to be used on the soil in place of manure. Rotting will be hastened if the compost pile is kept compact and moist. To ensure an early start in the spring, the manure should be cleaned out of the hotbed.

Perennial flower-beds should always be covered with fine, well-rotted manure, which can often be used with advantage on lawns also. The covering should be applied just at freeze-up. The manure helps to hold a snow blanket over the plants and adds fertility to the soil. When the manure is raked off

in the spring, the finer parts are left and should be dug in around the plants.

In localities where the land is heavy, the garden should be dug or ploughed in the fall and left in the rough all winter. The winter's frosts help to break up the clay lumps and make the soil friable and easy to prepare for early spring planting. A trench for sweet peas may also be dug in the fall.

Before the frost comes, a supply of rich, sandy loam should be taken indoors. It will be needed for planting winter bulbs, slips of house plants, and annual flower seeds. A sack of well-rotted manure and some sand will also be useful.

WHEN AND HOW SHOULD VEGETABLES BE HARVESTED?

The proper time to harvest vegetables depends chiefly upon their maturity and upon the manner in which they are to be used.

Peas and beans should be gathered young and fresh for serving green.

Beets and carrots require thinning from time to time; some of them, therefore, should be pulled and used during the growing season, and the rest should be harvested and stored before freeze-up.

Cabbage is ready for use as soon as it develops a large, solid head. Vegetables such as cabbages and turnips will stand some frost, but they should not be exposed to heavy freezing.

Only a part of the parsnip crop should be harvested in the fall; the rest of it should be left in the ground and dug up in the spring before there has been an opportunity for much growth to take place.

Tomatoes should be picked from the vines as they ripen; or, if they are late, they may be gathered green and ripened indoors.

Onions should be pulled when they are ripe, usually during the month of August. Before being stored for the winter,

they must be properly dried out, so that there will be no danger of them rotting. If the weather is dry and sunny, they may be left on the ground for a week or more until they are thoroughly cured. The tops should then be twisted off.

Potatoes should be dug in the fall after the tops are dead, unless danger of frost makes earlier digging advisable. The work should be done on a fine, dry day, so that very little soil will cling to the potatoes. What soil remains on them will shake off in the handling after a few minutes' drying in the sun and the wind. Wet, muddy vegetables should never be put in a storage room, as they are likely to rot.

A well-planned storage room. What provision is made for storing the various kinds of vegetables?

STORING VEGETABLES

To keep our bodies healthy we must include fresh vegetables in our diet all the year round. Vegetables that are to be kept for use during the winter months are usually stored in the cellars of our homes. A suitable storage room for vegetables can be made by carrying out the following instructions:

1. Board off a suitable portion of the cellar.
2. Cover the partition both inside and out with felt paper to keep out the heat from the furnace.
3. Lay a false floor over part of the room, and nail slats to the walls around this floor.

4. Screw several hooks into the ceiling.
5. Provide a few slat boxes and old sacks.
6. Build a few bins on one side of the room.
7. Store some sand in one of the bins.
8. Hang a thermometer in the storage room.

The size of the room will depend upon the size of the family and also upon the space available. A good storage room must be dark and cool (a temperature of from 35 to 40 degrees Fahrenheit is best); it must be well ventilated with moderately moist air, and protected from frost. Poor ventilation and excessive dampness favour the spread of disease and decay. On the other hand, if the air is exceedingly dry, too much moisture will evaporate from the vegetables, leaving them shrivelled and shrunken.

Before placing vegetables in the storage room, care should be taken to see that they are sound, dry, and clean. Potatoes should be piled on the false floor, against the slatted walls to ensure ventilation. They should be sorted over occasionally, and all decayed tubers should be removed and sprouts broken off. Cabbages should be stripped of their outside leaves and hung by the stem end from hooks in the ceiling. Carrots, beets, turnips, and parsnips are usually stored in sand to prevent them from becoming dry and soft. When boxes are used, a little damp sand should be placed in the bottom of the boxes, and on this should be laid alternate layers of vegetables and sand. To keep the sand slightly moist, it may be necessary to add water from time to time. Onions, if they are dry and well cured, should be placed in slat boxes or shallow trays, and may be stored either in the storage room or in the attic. Tomatoes may be treated in either of two ways: each fruit may be wrapped in paper, and left to ripen in a closed box in a warm room, or the vine may be pulled before there are any signs of frost, and suspended from the ceiling of a dark room in which the temperature is about 60 degrees Fahrenheit.

The following table sums up the main points to be remembered in storing the various kinds of vegetables for the winter.

STORAGE CHART

VEGETABLES	BEST TEMPERATURE	WILL KEEP UNTIL	REMARKS
Beets	33°—38° F.	May	Will keep best in sand.
Carrots	33°—38° F.	May	Will keep best in sand.
Cabbage	32°—37° F.	March	Provide good ventilation between heads.
Cauliflower	33°—38° F.	December	Hang head downward. Do not allow heads to touch.
Onions	35°—40° F.	May	Keep in shallow layers or shelves, trays, or slat boxes.
Parsnips	33°—38° F.	May	Keep in slightly moist sand. Leave some in ground all winter.
Swede Turnips	33°—38° F.	May	Keep fairly dry. Easy to store.
White Turnips	33°—38° F.	April	Keep in sand or boxes.
Tomatoes	50°—55° F.	December	Wrap individually in paper, or suspend vines from ceiling.

Something to Do

1. Visit a vegetable garden. Help the gardener to harvest and store the vegetables for winter use.
2. Make a plan, drawn to scale, of an attractive garden. Show the location and arrangement of the flower-beds, lawns, garden furniture, trees, and shrubs, and the chief varieties of flowers.
3. Gather flower seeds of mature plants to sow next year in your garden. Keep the different varieties in separate envelopes. Record on each packet the name, colour, and height of the variety.

4. Take pictures of some especially interesting features of gardens that you visit. Mount prints of them in your science note-book.

5. Make a collection of fruits of trees, shrubs, and flowering plants. Arrange them in groups according to the manner in which their seeds are dispersed, e.g. by wind, by explosive pods, or by animals. Try to make your collection attractive and informative.

6. Help to organize a "bee" to clean up your school grounds before winter sets in.

A young geranium plant that was grown from a slip.

Review Questions and Exercises

1. Give two good reasons why we should have flowers around our homes and at school.

2. What fall work is necessary to prepare the garden for winter and for early spring planting?

3. What precautions are necessary in harvesting the following vegetables: green peas, cabbages, onions, potatoes, tomatoes?

4. Why is each of the following conditions necessary to store vegetables satisfactorily for winter use: good ventilation, moderately moist air, and a cool temperature?

5. Write in your science note-book a description of a room that would be suitably equipped for storing vegetables.

FLOWERS FOR THE SCHOOLROOM

Almost one-half of the time you are awake you spend in school. Then why not make the schoolroom as cheery and pleasant as possible by the addition of a few colourful geraniums or other suitable plants? You might bring some plants from home when school opens after the summer vacation. You

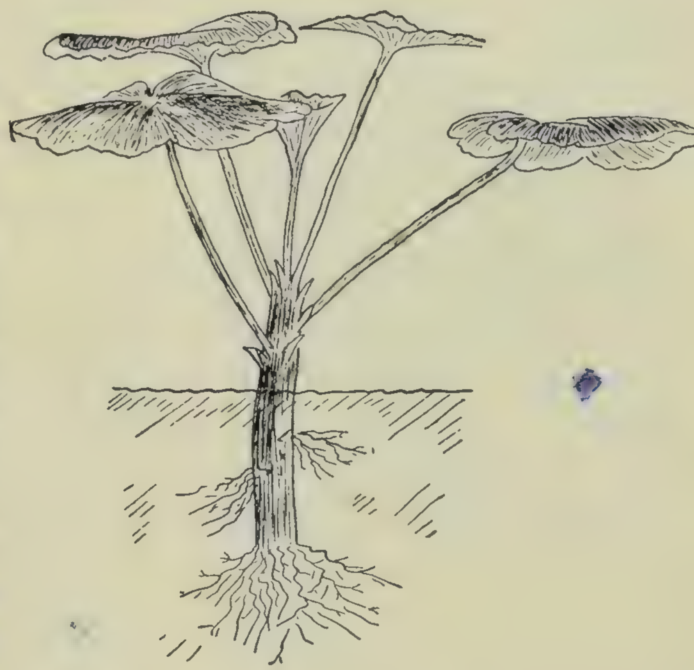
may arrange to take them home again when the cold weather sets in in the fall, if there is danger of freezing at school.

START PLANTS FROM SLIPS.

A few touches of natural beauty and colour add charm to any room. Some attractive plants that may be grown from slips are: geraniums, foliage plants, begonias, and wandering-jew.

Something to Do

Select a vigorous shoot, about three or four inches in length, that has been growing rapidly. Cut it off where it joins the stem. Remove some of the leaves—three or four are enough to leave on it. Set the slip in water, and keep it in a light, moderately warm place. Add fresh water as it is needed. Do not expect roots too soon. If after a few weeks roots have not developed, it may help to plant the slip in soil that is fairly sandy.



A well-rooted geranium slip. Notice the depth at which it is planted and the number of leaves remaining on the shoot.

Many slips may be rooted in clean sand or soil. Keep the sand moist but not saturated. It is a good plan, after the first few days, to allow the sand to become quite dry before watering it again. This allows air to get in around the slip and helps to keep it in a healthy condition. You will soon learn how much water to give your slips.

Flower pots, tin cans, or chalk boxes may be used for potting rooted slips. Bind chalk boxes with wire to prevent them from warping. Whatever type of container you use, it must have a

hole or holes in the bottom. Carefully pile small stones or bits of crockery over the holes to ensure good drainage. Partly fill the container with fairly rich garden soil to which has been added a little fine sand. The soil should be moist but not wet. Then plant the slip with about two-thirds of the stem below the top of the container. Be sure to spread the roots out well. Press the soil lightly about the roots. The pressure to be used will depend upon the dampness of the soil. It is better to leave the soil a little too loose than to pack it too hard. Fill the container with soil to within half an inch of the top. Finally, water the slip thoroughly. This will help the roots to establish themselves by packing the soil around them. Keep the slip out of the direct sunlight, but not in the dark, for a day or two. Then place it in a sunny window.

HOW TO CARE FOR HOUSE PLANTS

Plants grow best in a temperature that is kept uniformly at about 60 degrees Fahrenheit. As the temperature indoors is usually higher than this, you should set your house plants in the cooler part of the room, probably on the window-sills.

The air in which plants are to be grown must not only be cool; it must also be moist. There is no danger of having the atmosphere too moist, or humid, for plants. If your home or school is heated with hot air, keep the water pans in the furnace filled. If you have a hot-water heating system, hang on the radiators humidifiers or pans, from which water may evaporate. You may also increase the humidity by keeping a pan or kettle of water boiling on the cook stove. Humid air is good for people as well as for plants.

Water your plants regularly and properly. The amount and the frequency of watering should be determined by the kind of plant, its leafiness, the sandiness of the soil, the temperature of the room, and the size and nature of the container. Examine your plants daily to see if the soil is dry. Give each plant enough water at one time to soak to the bottom of the container. The soil is moist to the bottom when the

water runs out of the drainage holes into the saucer, provided it has not merely run down between the soil and the container (to avoid this, press the soil against the container with the fingers). Let the soil become fairly dry between waterings. Too much and too frequent watering drives the air out of the soil, and the plant becomes "sick." Make sure that the container drains properly. Do not allow excess water to stand in a jardiniere or saucer. Use soft water if it is available; hard water contains salt materials that are often injurious to plants. Stirring up the top soil now and then encourages healthy growth.

A begonia plant well started.

Wash the foliage occasionally with water to remove dust; when dust is allowed to accumulate, it interferes with the work of the leaves. Washing may be done with a fine hand spray or with a sponge, but a better and easier method is to set the plant outside during a warm, gentle rain. This will improve both its appearance and its health.

All plants must have light, but they do not all require the same amount. In general, flowering plants need more light than foliage plants, and ferns require less. Set your flowering plants, therefore, in a window with a southern exposure, and your ferns in a west or a north light. Turn the plants from day to day so that all parts of them may receive the light, and thus enable them to grow erect and develop uniformly on all sides.

Insects bring death to house plants. Watch carefully for the appearance of plant lice or aphids, mealy bugs, red spiders, etc. Healthy ~~plants are not so~~ likely to become infested as sickly ones. Geraniums are seldom attacked by insect pests. If plants are washed regularly with soapy water, insect pests can

usually be kept under control. Should aphids become a menace, spray your plants with a suitable chemical solution.

NOTE.—For washing plants, use one ounce of laundry soap to one quart of water. For a spray, use Black Leaf 40, which may be purchased from a florist. Mealy bugs must be washed off the plants; Black Leaf 40 or similar sprays will not destroy them. A helpful bulletin to consult on this subject is *Insects Affecting Greenhouse Plants,* Bulletin No. 7 N.S., Department of Agriculture, Ottawa.

A bowl of mixed hyacinths—King of Blues and Queen of Pinks. (Photo by Kenneth McDonald & Sons, Ottawa)

Remove dead leaves and withered blooms regularly, and clear away from the top of the soil all dead plant material and other rubbish. Such material attracts insects and is unsightly.

Something to Do

To stimulate growth and bloom in your house plants, use vitamin B1. This preparation may be purchased from seed supply houses or from florists. Or apply special plant fertilizers from time to time. Be sure to follow the directions that come with the vitamin B1 and the plant fertilizers. Failure to do so may lead to disappointing results.

HOW TO GROW A BULB

For indoor cultivation the common winter flowering bulbs, such as tulips, hyacinths, and narcissi, are best. They possess great beauty, and can be obtained in a large selection of

A Bulb

"I placed it in the earth — this bulb of mine —
And from its narrow prison house at night
It struggled forth to reach the air and light;
And as it rose and blossomed to the sight,
Its absolute perfection seemed divine!"

J. C. Ascher

colours. They thrive and produce lovely blooms under a wide range of conditions. Try growing some bulbs this winter; follow the directions given below for planting and caring for them. By careful planning you can have a succession of bloom to brighten your schoolroom or your living-room at home throughout the cold winter months.

Something to Do

Secure a fall bulb catalogue from a reliable seed company or nursery, and make your selection of plants from it. For table and window display, tulips, hyacinths, and narcissi are most commonly grown. In selecting tulips, choose either the Early or the Darwin varieties, preferably the latter. They can be obtained in many shades. Of hyacinths, the Dutch is the best. Three varieties suitable for beginners are: L'Innocence (white), Queen of Pinks, and King of Blues. For your narcissi (daffodil) plants, choose Paper White, Chinese Sacred Lily, and Bicolour Empress. As tulips and narcissi are much cheaper than hyacinths, it might be well to experiment with them first.

Time of Potting.—Early tulips and paper white narcissi should be potted in September or early October. If you are using a number of Darwin tulips or Dutch hyacinths, plant some of them about the first of October, more two weeks later, and so on until the middle of December. This will provide for a succession

preparation

of bloom throughout the winter. If you plan to grow only a few bulbs, pot them all early in October.

Containers.—Standard flower pots are best, but you may use tin cans if you punch holes in the bottom to provide drainage. The size of the pot required depends upon the size and the number of bulbs to be planted in it. Tulips may be planted singly in three-inch pots, or in groups of three in five-inch pots. Hyacinths, being larger bulbs, require a little more space.

An attractive pot of tulips. (Photo by Kenneth McDonald & Sons, Ottawa)

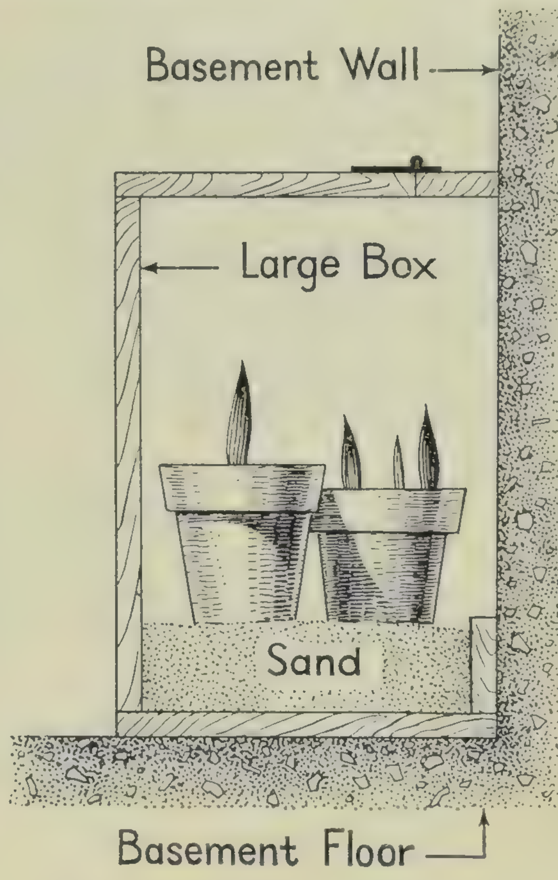
Soil.—Use a mixture of rich loam and sand in the proportion of 3 to 1. You can increase its fertility, if necessary, by thoroughly mixing into it some well-rotted manure (preferably cow manure) or some leaf-mould. Use three parts of soil to one part of manure.

Planting. — In planting, be very careful to place the bulb at the proper depth in the soil and to pack the soil firmly. Cover the drainage hole in the bottom of the pot with small stones or pieces of crockery. Put some soil into the pot, and pack it lightly, if it is not too damp. Add more soil, and pack it again. Continue this until by trial you find that, when the bulb is placed on top of the soil, its tip is about half an inch below the top of the pot. Spread the roots out well, and add more soil, packing it lightly around the bulb until the tip is just covered. Finally, water the soil thoroughly to settle it and bring it into close contact with the bulb. Add more water from time to time to keep the soil moist.

Root Development.—In order to produce large blooms, a bulb must develop a strong root system before shoot growth commences.

This is readily accomplished, because the best temperature for root growth is lower than that for the growth of the shoot. Keep newly potted bulbs in a cool place (from 38 to 40 degrees Fahrenheit) until the pot is literally full of roots. Roots will extend through the drainage hole when full growth has taken place. Do not be impatient. It will take two or three months to establish a well-developed root system. Add water as often as necessary to keep the soil moist.

After Care.—When you are sure that the roots have developed sufficiently, bring your bulbs to full light and warmth gradually. The blooms will last longer if the bulbs are kept in a place that is not too warm.



A convenient method of shutting out the heat from a few bulbs—a large box with the open part shoved against the basement wall. A hinged top would be handy. The sand encourages root development, but bulbs can be grown successfully without it if it is not available.

GROWING BULBS IN WATER

Though paper white narcissi and Chinese lilies can be grown in soil, in the same way as tulips and hyacinths, it is more interesting to grow them in water, supported by stones.

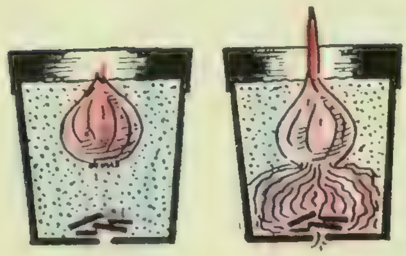
Something to Do

For a container, use a low bowl or a deep dish. Cover the bottom of the container with small stones or sand. Support the bulbs in an erect position by placing stones around them. Then add water until more than half of the bulb is submerged. The container may then be placed in the light in a cool part of the room. If the temperature is much above 65 degrees Fahrenheit, the shoot will develop too quickly, and the flowers will be inferior.

Also, if the temperature is not too high, the blooms will last longer. When grown in water, paper whites should produce blooms in about six weeks. By starting a few bulbs every two weeks, you may have continuous bloom throughout the winter.

Review Questions and Exercises

1. Describe a method of producing roots on a geranium slip.
2. What conditions are necessary for the healthy growth of house plants? How are these conditions provided in the average home or school?
3. Why is a good growth of roots necessary in order to produce large blooms on bulbs?
4. Discuss the growing of winter-flowering bulbs under the following headings: *kinds of bulbs, time of potting, containers, soil, planting, root development, care while blooming.*
5. Describe the method of growing bulbs in water. What kinds of bulbs can be grown satisfactorily in this way? How can you provide for a succession of bloom?



A, a bulb that has just been potted. B, the same bulb, well rooted, and ready to be brought into the light.

Something to Do

Outline a good way to solve each of the following problems:

1. What fall preparation is necessary: (*a*) to have three pots of Darwin tulips in full bloom in March? (*b*) to grow radishes and lettuce in the spring before the outdoor growing season begins?
2. Suppose that, in the fall, you have a large, healthy geranium plant. What method would you follow to produce from the large plant four plants that would be of proper size and in bloom for your window-box in the spring?
3. What conditions might cause a bin of potatoes to begin to spoil? How would you proceed to save the good potatoes in a bin in which you found a number of spoiled ones?
4. You have a house plant that is not thriving. Make a list of the probable reasons for its condition, and state how you would overcome each.

From a painting of a forest of the "Coal Age" by
G. A. Reid, R.C.A., in the Royal Ontario Museum

Heat enriches and transforms,
Gives the reed and lily length,
Adds to oak and oxen strength,
Transforming what it doth unfold,
Life out of death, new out of old.

—RALPH WALDO EMERSON.

CHAPTER FOUR

CHAPTER 4

HEAT PROMOTES LIFE

A little over a hundred years ago, even the greatest scientists believed that heat was a liquid that flowed into bodies when they became hot. Now we know differently. Do you know what heat is? What interesting changes does heat make in substances? How has knowledge of heat added to man's comfort and convenience? Why does a fire burn?

Warmth is necessary to all forms of life. We find ample proof of this in nature in the fall. As cold weather approaches, some plants die. Others undergo marked changes as they prepare for winter. Insects find themselves hiding places and remain inactive as long as the cold weather lasts. Animals like the gopher and the bear sleep all winter in homes that they prepare beneath the snow. In the north, animals survive only by growing heavy layers of fat and thick coats of fur to keep them warm. The life processes of many living things slow up in the fall or cease altogether through lack of sufficient heat.

In the spring, all life quickens. Warmth "wakens" the seeds, and they germinate and grow. Insects come out of their hiding places. Animals that have been idle all winter once more become active. Everything seems glad when the warmth of spring returns.

WHAT IS HEAT?

Since we have learned how to produce and control heat, we have found many ways of putting it to work. We use

Scientists have learned how to use heat in making pottery from clay. In the process the articles are baked in ovens. (New Brunswick Government Information Bureau photo)

heat to warm our homes and to cook our food; to turn water into steam to run our engines; to kill germs that might endanger our health; to soften metals and other substances for moulding into myriads of useful shapes. Since in these and many other ways heat has the ability to do work, it is a form of energy.

Test

THE SUN IS OUR CHIEF SOURCE OF ENERGY.

The rays of the sun travel outward in all directions. Those that reach the earth bring us light and heat. If you will think for a moment, you will realize that most of the world's supply of heat comes from the sun. Energy secured from the sunlight is stored up in green plants, through the action of the colouring material in them. It is passed on by the plants, in the form of food, to animals, and is used up in their bodies to keep them warm. We secure our heat by burning coal, wood, oil, gasoline, and other fuels. Fuels are substances that, when burned, release heat. They have all been produced from plants or plant material. Therefore, the heat or energy that they possess came originally from the sun.

Use the diagram at the top of the next page to show that electricity is another source of heat that may be traced back to the sun.

Swiftly flowing water drives great machines in this power house to generate electricity for many purposes. Explain how the energy of the sun raises the water to the levels from which it flows.

MAGIC BY HEAT

Heat has the power to transform many substances.

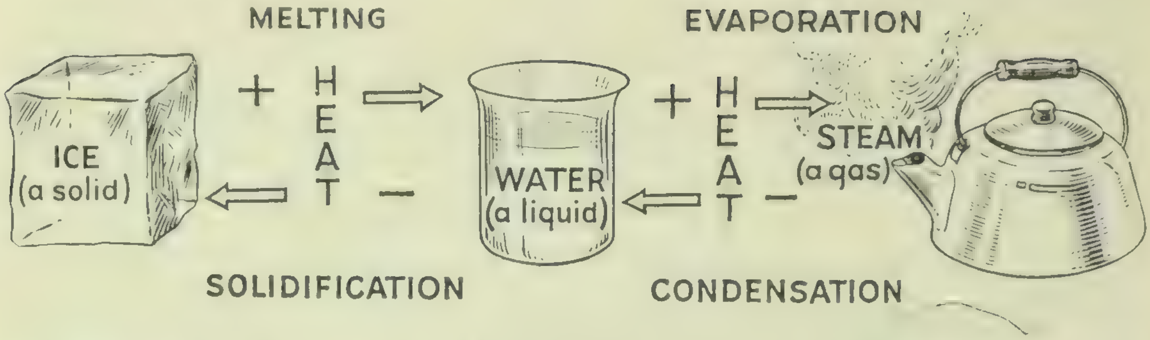
The rays of the sun shine on a pond and develop heat. Some of the water is soon changed by the heat energy into an invisible form called water vapour. We say that the water evaporates. The water vapour is carried up and up by the breeze to levels where the air is much cooler than it is nearer the earth. Since water cannot remain in the form of water vapour without the presence of heat, soon another change occurs, and the water vapour becomes water once more. First, tiny droplets of water are formed. Then clouds appear. Finally large drops of rain form; the rain falls on the hills; streams develop, and the water runs back into the pond again.

A workman takes a piece of iron, heats it until it becomes red hot, then, while it is soft, fashions it into many wonderful things. If he heats it sufficiently, it becomes liquid or molten iron. The heat from the flame of a candle melts the

Molten steel is being released through a small hole in the bottom of the "ladle" in the upper left corner into a steel "basket," from which it pours into the "ingot" moulds below. The workmen must be skilled and experienced to make use of heat successfully in such an operation. (Toronto Chamber of Commerce photo)

wax of which the candle is made. A warm day may reduce butter almost to the form of oil. Under the influence of heat, ice, which is a solid, changes into water, which is a liquid. On the loss of heat, the liquid forms of iron, butter, wax, and water are again changed; they solidify, or become solids, once more.

These examples illustrate only a few of the changes that are brought about in substances by the energy of heat: namely, that heat causes solids to become liquids, and liquids to become gases; and that loss of heat changes liquids into solids and gases into liquids. Many other effects of heat upon substances have been discovered by scientists from time to time. Experiments have shown, for example, the temperature at which different solids melt, the conditions under which various fuels burn, and the amount of heat required to cause liquids to evaporate. The facts brought to light by scientists have enabled us to use heat to advantage in many ways. But as in all other fields of science, a great deal yet remains to be learned about heat and its effects.



Explain the changes from solid to liquid, from liquid to gas, from gas back to liquid, and from liquid back to solid that are illustrated in this diagram. Follow the plus and minus signs and the arrows. Note: Water in a gaseous form is present just at the mouth of the tea-kettle spout. Almost immediately it cools and forms a cloud of tiny particles of water.

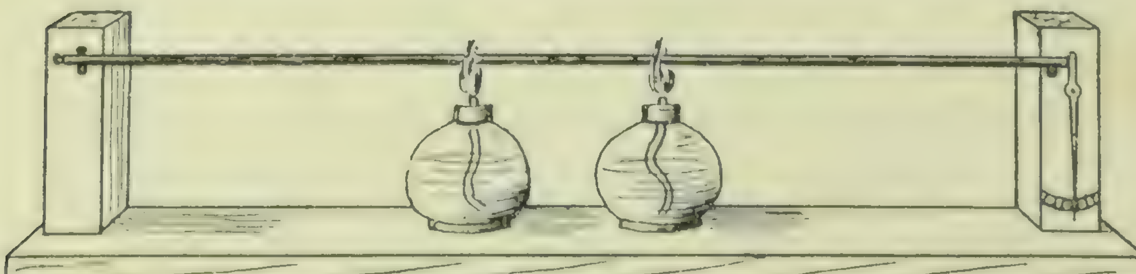
MORE EFFECTS OF HEAT

One bright, cold day in winter, Bob and his father were enjoying a hike. As they crossed a railway track, Bob noticed spaces between the ends of the rails in the track. When he asked why the spaces were there, his father suggested that, instead of explaining the reason, he should help Bob to discover it for himself by performing an experiment. Here is the experiment that Bob's father described. You, too, can perform it to find the answer to Bob's question.

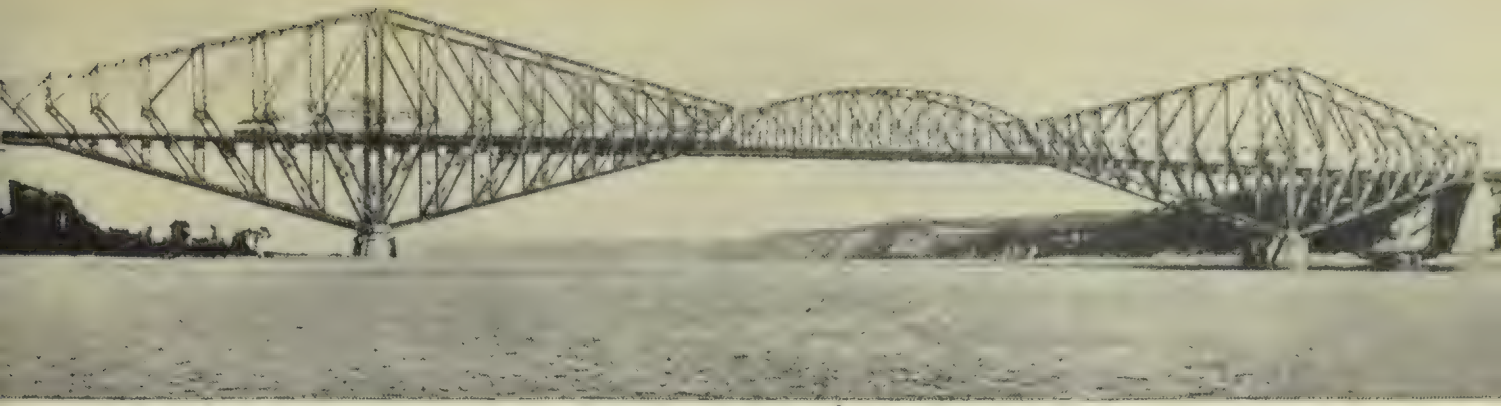
Something to Do

1. *Problem.*—Has heat any effect on the volume of a solid?

Apparatus and Material.—Arrange an iron rod as shown in the diagram below. Fasten one end of the rod solidly by means of three small nails. Allow the other end of the rod to rest



What will happen to the pointer when the iron rod is heated? Why?



The Quebec Bridge. It has the longest cantilever span in existence—eighteen hundred feet. What provision must be made in such a bridge for expansion and contraction of the metals used? (Canadian Government Motion Picture Bureau photo)

loosely on another nail so that it just touches the upper part of the pointer. Have alcohol lamps available.

Method.—Notice carefully the position of the pointer when the rod is cold. Then heat the rod, and again observe the position of the pointer. Allow the rod to cool, and once more check the pointer.

NOTE.—If alcohol lamps are not available, try one of the following suggestions: (*a*) Make the supports tall enough to hold the rod about half an inch above the top of the chimney of a kerosene lamp. (*b*) Arrange the rod so that it can be removed and held over a fire, using one or two pair of pliers. Note the position of the pointer before and after heating the rod. (To avoid burns, the teacher should carefully supervise these procedures.)

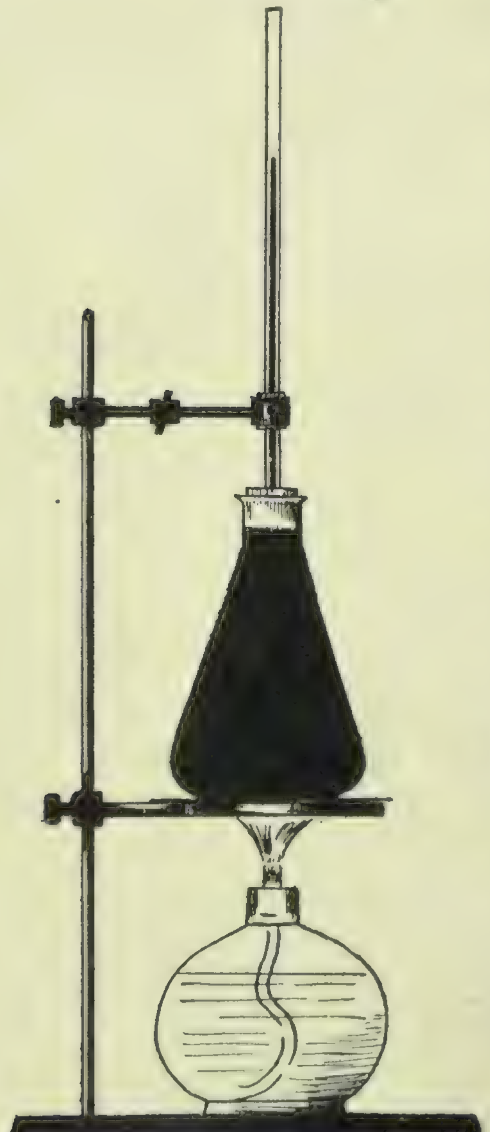
Observation.—What change takes place in the position of the pointer? What does this show you about the effect of heat on the length of the rod? As the rod cools, what happens? What does this show?

Conclusion.—In your note-book report, include the following sentence, filling in the blanks with the words *expand* or *contract*: Most solids _______, when heated and _______ when cooled.

2. A second experiment may be performed as follows: Obtain a washer that just fits over a short iron rod. It may be necessary to secure a piece of iron rod slightly too large to slip into the washer, and to file it down carefully until an exact fit is obtained. Now heat one end of the rod, and again try to fit it into the washer. What has happened? Plunge the rod into some water to cool it. Try to fit it into the washer again.

Application.—Try to find devices that make use of the principle of expansion and contraction of solids by heat and cold.

The appliance that is used to regulate the temperature of an egg incubator is an example of one such device.



What happens when the coloured liquid in the flask is heated?

John and his father went to a service station to fill the tank of their automobile with gasoline. After they arrived home, they left the car standing for a time in the hot sun. Later, John noticed gasoline dropping from the overflow pipe of the gasoline tank. Why did gasoline run out of the overflow pipe after the car had stood in the warm sun, when no gasoline had run over at the filling station? Find the answer by doing the following experiment.

Something to Do

Problem. — Do liquids expand when heated and contract when cooled?

Apparatus and Material.—Water; a flask or a suitable bottle; a one-holed rubber stopper; glass tubing; an alcohol lamp; a retort stand; an iron ring; and a wire gauge.

Method. — Fill the flask with water. A little colouring material, such as red ink, may be mixed with the water. Insert one end of the glass tubing into the stopper. Fit the stopper into the mouth of the flask. Mark the height of the water in the glass tubing. Heat the water, and observe any change in the height. Allow the water to cool, and check the height.

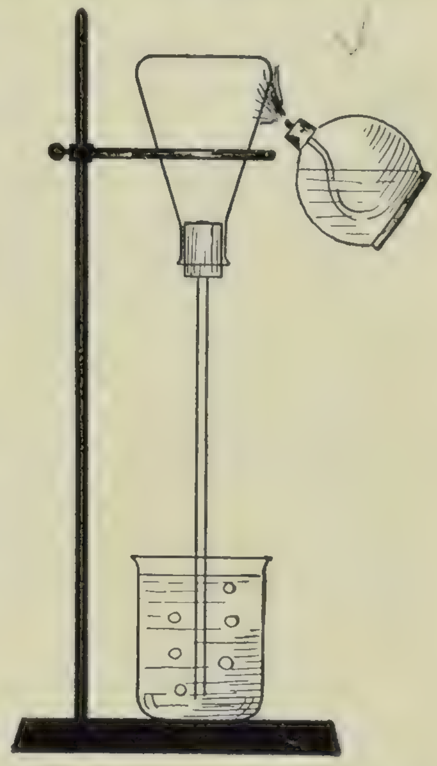
Suggestions.—A straw, which you can obtain from a confectionery store, may be substituted for the glass tubing in this

experiment. The flask or bottle full of water may be heated by immersing it in a vessel of warm water.

Observation.—Does the water rise in the glass tubing when it is heated? Does it fall when allowed to cool? What do these observations indicate?

Conclusion.—Using the words *expand* and *contract,* summarize in a brief statement the results obtained in your experiment.

We have now found that solids and liquids expand when heated and contract when cooled. How do gases behave under similar conditions?



How does air (a gas) behave when heated and cooled?

Something to Do

Problem.—What effect has heat on the volume of a gas?

Method.—Insert one end of a piece of glass tubing into a one-holed rubber stopper. Fit the stopper into the mouth of a flask or a glass bottle. Now dip the other end of the glass tubing into a beaker or tumbler of water. Heat the flask *gently* with an alcohol lamp to warm the air inside. (Just brush the flame against or near the flask; if you hold it too long in one place, you will crack the glass. Be careful not to spill any of the alcohol that is in the lamp.) When a few bubbles have escaped through the water, remove the heat. Watch what happens.

NOTE.—The flask or bottle may be heated by holding it in your hands (be sure your hands are warm) or by pouring warm water over it.

Observation.—Since some of the air in the flask is forced out as soon as the air is heated, what must happen to a gas, such as air, when it is heated? As soon as the air in the flask cooled again, water rushed in. What does this indicate must happen to the air when it is cooled?

Conclusion.—Summarize the results of this experiment by stating very briefly the facts you have learned about the expansion and contraction of gases when heated or cooled.

ALTERNATIVE EXPERIMENTS.—1. The egg and milk bottle experiment outlined on page 9 illustrates the expansion and contraction of air when heated and cooled.

2. Tie a piece of thin rubber (a part of a rubber balloon) over the mouth of a wide-mouthed bottle. Set the bottle in a vessel filled almost to the height of the bottle with warm water. Why does the rubber bulge outward?

WATER, WHEN COOLED, BEHAVES IN A WAY OF ITS OWN.

Most substances contract more and more as they become cooler. You have already performed an experiment in which you found that water contracts when it cools. But you have no doubt noticed that milk, as it freezes, expands and pushes the top out of the bottle that contains it. So, too, water, if it freezes in a pail, first bulges, then breaks the pail. These common examples suggest that, when water becomes cool enough to freeze, it expands instead of contracting, and so increases its volume.

What actually happens in the case of water is that, as it cools, it contracts more and more until its temperature is just above the point at which it freezes. Then it expands until it reaches the freezing point. It has been found that the volume of water increases about one-tenth when it freezes. Therefore, a cubic foot of ice weighs less than a cubic foot of water. This is the reason that ice floats.

In the fall, the water on the surface of ponds and lakes cools, and as it does so, it contracts. Because it contracts, it becomes heavy and sinks to the bottom, pushing the warmer water up. Again the surface water is cooled and contracts, and the process is repeated until finally the whole lake cools to a few degrees above freezing point. The surface water then expands and freezes. As it freezes, it becomes lighter, so that it stays on top and forms a sheet of ice over the pond

or lake. Unless the water is quite shallow, the ice sheet over the top keeps the rest of the water warm enough to prevent it from freezing.

If, in the winter, the water in all lakes froze to the bottom, serious results would follow. Fish and other animal life would be destroyed. The water supply of many large cities would be shut off. In many places the ice in the bottoms of the lakes would never melt during the summer.

Sometimes this peculiar property of water is a nuisance, for example, when it breaks the radiator of a car on a cold night; but, on the whole, it seems to be a good thing that water behaves as it does when it freezes.

Review Questions and Exercises

1. What is heat?

2. What is our chief source of energy? Give at least one example to show how energy is obtained from this source.

3. When a solid melts, does it gain or lose heat?

4. When water vapour in the air is cooled sufficiently, how does it change in form?

5. Outline an experiment to learn the effect of heat on the volume of a solid.

6. Make a diagram of the apparatus used to find the effect of heat on the volume of a liquid. Devise some way of showing the result of the experiment in your diagram.

7. How would you prove that gases expand when heated and contract when cooled?

8. Briefly explain the meaning of the terms: *evaporation, condensation, expand, contract.*

9. Describe the peculiar way in which water behaves as it freezes.

10. The screw top of a fruit sealer that is stuck can sometimes be loosened by dipping the top in warm water. Can you explain the reason?

11. Why do clothes on a line dry more quickly on a warm day than on a cool day?

12. When iron bridges are built, spaces are left in certain parts to allow for expansion. Why is a metal bridge longer in summer than in winter?

TEMPERATURE IS NOT THE SAME AS HEAT.

What is the meaning of the term *temperature*?

Something to Do

Heat the end of an iron rod until it is quite hot (slightly red, if possible). Now thrust it into a small quantity of cold water. After a moment or two, feel the water and the iron. What has happened? The iron has lost some of its heat, and the water has become warmer.

When one object will give heat to another, the two objects are said to be at different temperatures. The object that receives heat is at a lower temperature than the object that loses it. *Temperature,* therefore, is the degree of heat or cold of one object as compared with another.

Temperature does not refer to the amount of heat in an object. If a cupful and a pailful of water are allowed to stand in the same room for some time, their temperatures will become the same. But it is evident that there must be more heat in the pailful of water than in the cupful. More fuel would have to be burned to raise the pailful of water from a low temperature to a higher one than would be required to do the same to the cupful.

HOW IS TEMPERATURE MEASURED?

Can we rely upon our sense of touch to determine the temperature of a substance? Before answering the question, perform the following experiments.

Something to Do

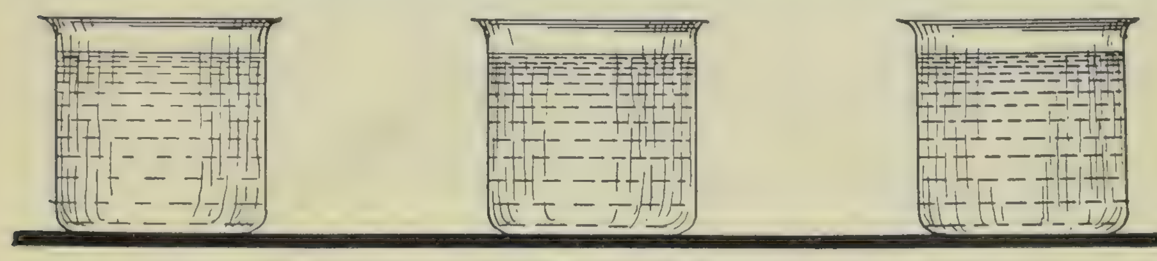
1. *Apparatus and Material.*—Three tumblers, beakers, or cans, one containing cold water, another containing hot water, and the third containing luke-warm water.

Method.—Hold a finger of one hand in the cold water and a finger of the other hand in the hot water for the space of one or two minutes. Then quickly put both fingers into the luke-warm water.

Observation.—How does the luke-warm water feel to the finger you have had in the cold water? How does it feel to the finger you have had in the hot water?

Conclusion.—Write a statement answering the question asked at the beginning of this section.

2. All parts of your desk will be at the same temperature, that is, at the temperature of the air in the room. But with your finger touch first the iron and then the wooden parts. Which feels colder? Remember that both are at the same temperature. Can we rely upon our sense of touch to determine temperature?



A beaker containing water that is very much colder than your hand.

A beaker of water that is just as warm as your hand.

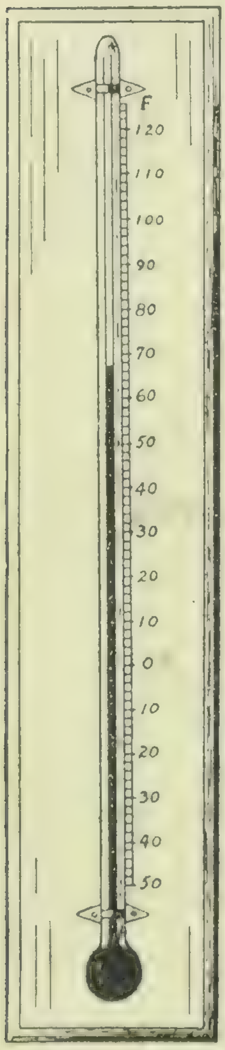
A beaker of water that is as hot as your hand can endure.

It is evident that some instrument must be used for the accurate measurement of temperature. About three hundred and fifty years ago, a great Italian scientist, Galileo, invented the first thermometer.

HOW IS A THERMOMETER CONSTRUCTED?

Something to Do

Examine your schoolroom thermometer. Notice the long glass tube. Try to see the very fine opening or bore running lengthwise through it. Observe the bulb at the end. Does the thermometer you are observing contain mercury or coloured alcohol? Mercury is a shiny, silvery liquid. The alcohol used in thermometers is usually coloured red. Note the scale or



Why has the tube in a thermometer a very small bore? Why is water not a good liquid to use in a thermometer? What liquids are used?

graduations. Each division of the scale probably represents one or two degrees. What is the present reading? Hold your hand over the bulb. Observe the behaviour of the liquid. Can you explain why the liquid rises and falls in the thermometer tube? (See page 90.) Notice if a point on the scale is marked *boiling point.* This indicates the temperature of boiling water. Observe the *freezing point.* This marks the temperature at which water freezes. Notice that the freezing point is 32 degrees. The zero of the scale is therefore 32 degrees below freezing point.

This method of graduating or marking a thermometer was devised by *Fahrenheit* (fă'rĕn-hīt), a German instrument maker, over two hundred years ago. When a thermometer reading refers to the Fahrenheit scale, it is marked with a capital *F.*

Something to Do

Examine the scale on your thermometer to find the answers to the following questions:

1. How many degrees below freezing is the temperature when the thermometer reads 20°F., 12°F., 0°F., −12°F., −30°F. (the minus sign means *below zero*)?

2. How many degrees above freezing is the temperature when the thermometer reads 40°F., 68°F., 212°F.?

There is another scale that is used for graduating thermometers. It is called the *Centigrade* scale. On it the zero is placed at the freezing point, and the boiling point is marked 100. The Centigrade scale is used extensively for scientific work and is in general use among the people of France, Germany, and a number of other countries.

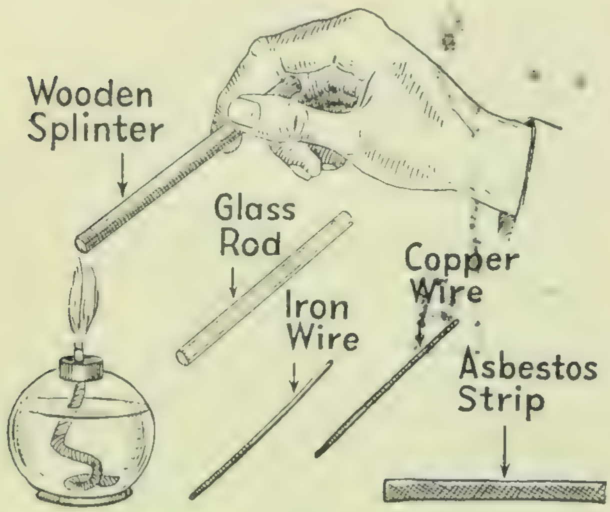
The Chateau Laurier, Ottawa. In what ways is heat used in our homes and other dwelling places? (Canadian National Railways photo)

Review Questions and Exercises

1. What is the meaning of the term *temperature*?
2. Is temperature the same as heat? Give a reason for your answer.
3. Outline an experiment to show that we cannot rely upon our sense of touch to determine the temperature of an object.
4. Describe the thermometer in your schoolroom or in your home.
5. How many degrees above or below freezing are the following thermometer readings: 16°F., −15°F., 50°F., 32°F?
6. What causes liquids in thermometers to rise or fall as the temperature changes?
7. Find out how thermometers are used in baking ovens, cooling systems of automobiles, and weather forecasting stations.

HOW IS HEAT TRANSFERRED FROM PLACE TO PLACE?

Through the work of scientists, we have learned not only how to produce and measure heat but also how to transfer it from one place to another. This knowledge we have put to use in many ways, as, for example, in building warm houses, in



Which materials will conduct the heat of the flame to the hand first? Which will not conduct heat at all? Name other good conductors and other good insulators of heat.

heating and ventilating our homes, in manufacturing thermos bottles and refrigerators. Heat can be transferred in several ways.

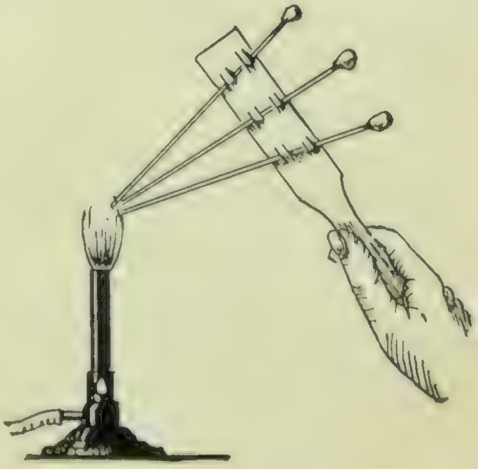
HOW IS HEAT TRANSFERRED THROUGH SOLIDS?

Mary was making candy on the kitchen stove. She left a metal spoon in the boiling mixture for several minutes. When she returned to stir the candy, she found that the handle of the spoon had become so hot that she could not hold it in her hand. How had the heat travelled from the hot part of the spoon to the cold part?

Place one end of an iron poker in a fire. What happens to the other end? How was the heat carried from the warm end to the cold end of the poker?

In both the spoon and the poker the heat must have travelled through the metal of which they were made. This method of transferring heat is known as *conduction*.

Now thrust one end of a piece of wood into a fire. You will find that little or no heat is conducted to the other end. This shows that wood is a poor conductor of heat. Metal, on the other hand, is a good conductor of heat. To test other substances, perform the experiment described on the opposite page.



Why does the wax placed on the ends of the wire away from the flame not melt at the same time?

Something to Do ✓

Problem.—To find some substances that are good conductors of heat and some that are poor.

Apparatus and Material.—An alcohol lamp; pieces of copper and iron wire; a glass rod or other piece of glass; a chip of stone; a small stick of wood; a piece of china; other materials, such as asbestos, if they are available. The pieces of materials used in performing this experiment should be about six inches long.

Method.—Hold one end of each piece of material in turn in your hand. Thrust the other end into a flame. Hold it in the flame until the heat reaches the end you are holding.

How does the experiment illustrated in this diagram demonstrate that water is a poor conductor of heat? Note that paper is used to hold the test-tube.

Observation.—Try to decide which of the substances transfer heat through them most quickly.

Conclusion.—List the substances that you have found to be good conductors and those that you have found to be poor conductors. Does your list of good conductors include such metals as silver, copper, brass, and iron? Under the heading poor conductors in your list have you included such substances as ice, water, stone, and glass?

NOTE.—A more accurate experiment is illustrated in the diagram on page 98. Use three wires of the same diameter but of different materials.

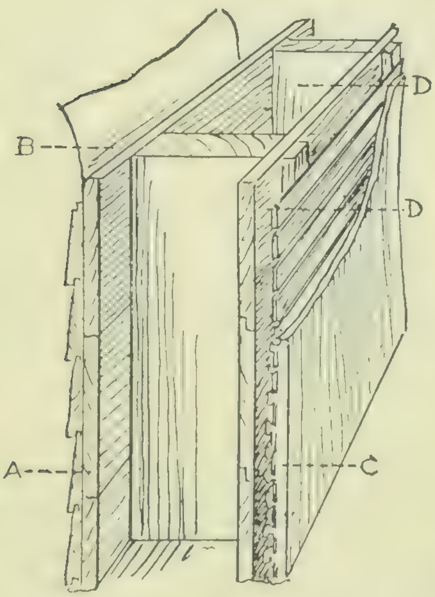
Application.—Why are tea-kettles, curling tongs, etc., provided with wooden handles? Why are the pipes of furnaces sometimes covered with asbestos?

IS WATER A GOOD CONDUCTOR OF HEAT?

To determine whether water is a good conductor of heat perform the simple but interesting experiment described at the top of the next page.

Something to Do

Heat some cold water in a test-tube as illustrated in the diagram on page 99. After the water in the top has been boiling for a minute or two, feel the lower end of the test-tube. Is it hot or cold? Is water a good or a poor conductor of heat?



A section of a wall. A, boards. B, paper. C, plaster. D, dead air spaces. How many layers of non-conducting material are there in this wall?

INSULATORS

Materials that are very poor conductors of heat, such as felt, asbestos, air, and paper, are known as *insulators* (ĭn′sū-lā-tors). They are often used to prevent the escape of heat.

WHY DO WOOLLEN CLOTHES KEEP US WARM?

Air, provided that it is motionless or "dead," is an excellent insulator. Large numbers of tiny air spaces are to be found throughout all woollen materials. Clothes made of wool, therefore, are poor conductors of heat and prevent the loss of heat from our bodies. Clothing of felt, flannel, and fur keeps us warm in the same way. Notice that warm clothes do not keep the cold out; they keep the heat in. Cold means the absence of heat, just as darkness means the absence of light.

Cloth made of linen, cotton, silk, or rayon, on the other hand, has few air spaces. Consequently it conducts heat away from our bodies readily and is, therefore, good material for summer clothes.

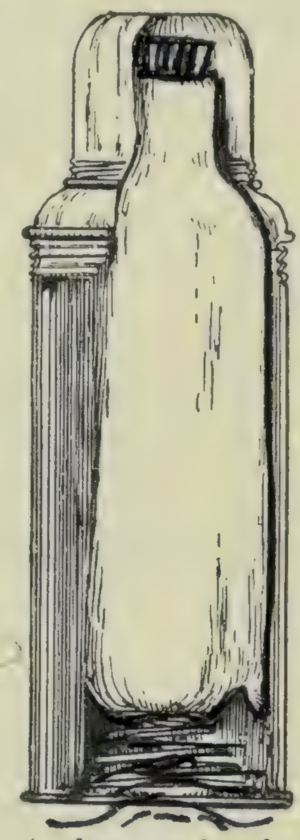
Feathers keep birds warm in the same way as woollen clothes keep us warm. Have you ever seen a bird fluff up its feathers on a cold day? How does this help to keep it warm?

WHY DO WE USE STORM WINDOWS?

Glass, as we have seen, is also a poor conductor of heat. But because the sheets of glass in our windows are very thin, much heat may be lost through them during the winter. To prevent this loss, we use storm windows. Thus we not only provide a double thickness of glass, but we also set up between the window and the storm window a dead-air space, which makes it difficult for heat to pass through the window.

THERMOS BOTTLES

A thermos bottle consists of two glass jars, one inside the other. The jars are joined together at the neck, and for protection are surrounded by a metal container. The air is removed from the space between the jars, leaving an empty space or *vacuum* (văk′ū-um). A vacuum is a perfect insulator of heat. Hot liquids are kept hot in a vacuum bottle, because the heat cannot escape through the glass and the vacuum. Cold liquids remain cold because heat cannot enter from the outside. Examine a thermos bottle to find the various parts as illustrated.



A thermos bottle. Give one reason why a thermos bottle keeps heat in.

HOW IS HEAT TRANSFERRED THROUGH LIQUIDS AND GASES?

If water and air are such poor conductors of heat, how does the air in a room become warmed by a radiator in one corner? How does a large kettle of water become hot when only one part of the kettle is in contact with the fire?

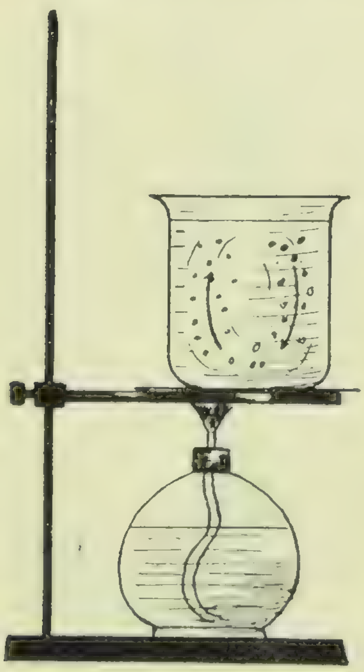
Something to Do

1. *Problem.*—How is heat transferred through a liquid, such as water?

Method.—Put a little sawdust in a beaker full of water. Arrange an apparatus as illustrated in the diagram below. Hold the flame of an alcohol lamp under one side of the beaker.

Observation.—Watch the movement of the particles of sawdust as the water becomes heated. Notice the current that is set up by the heat.

Explanation.—What causes this current? The flame heats the water just above it, thus causing the water to expand and become lighter. The colder water in the other parts of the beaker then presses in, forcing the warm water upward. In this way, a current, called a *convection* (kŏn-vĕk′shŭn) current, is set up in the water. The current will continue until all parts of the water are at the same temperature.



Why is a convection current, as indicated by the arrow, set up in the water in the beaker?

Conclusion.—State how heat is transferred through a liquid.

2. *Problem.*—How is heat transferred through a gas?

Apparatus and Material.—A lamp chimney; a cardboard partition; a saucer; water; a candle; a small piece of woollen cloth or a wooden splinter.

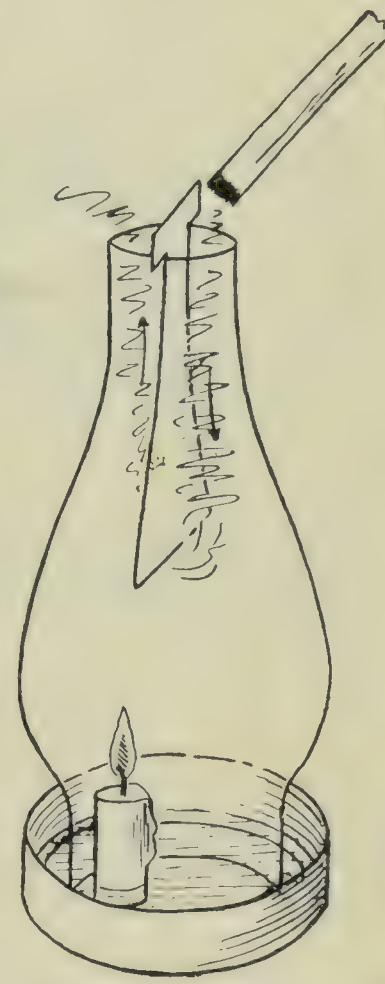
Method.—Cut a cardboard partition to fit the inside of the top of the lamp chimney, as illustrated in the diagram on the opposite page. Partially fold the partition in the centre, and insert it into the chimney. Then spread it flat again. The more snugly the partition fits, the better will be the results of the experiment. Pour a little water into the saucer. Light the candle, and place it in one side of the saucer. Arrange the chimney so that the candle is well under one side of the partition. Light a small roll of the cloth. Hold the smoking roll of cloth over the side of the partition opposite the candle, as indicated in the diagram.

Observation.—Notice how the smoke travels through the lamp chimney.

Explanation.—How does the smoke pass through the chimney? The heat from the flame of the candle heats the air around it. The air expands and becomes lighter. The cold, heavier air then presses down one side of the partition and forces the warm air up through the other side. Thus a convection current is set up in the air.

Conclusion.—State how heat is transferred through a gas.

NOTE.—Convection currents of air may be observed by clapping two blackboard brushes together over a warm radiator or hot stove. Try to trace the path of the chalk dust through the room.



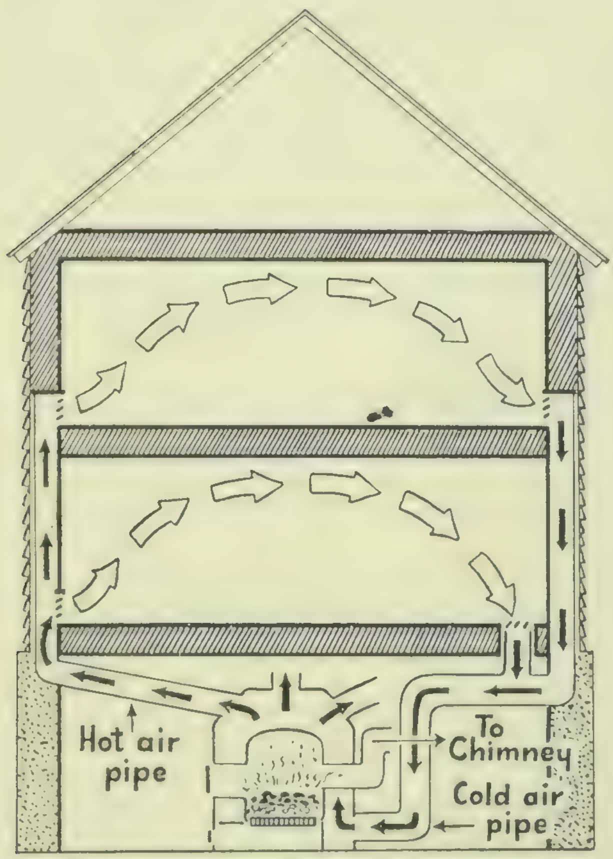
How does the flame of the candle affect the air above it? Account for the circulation of air as indicated by the arrows.

HEAT IS TRANSFERRED IN STILL ANOTHER WAY.

If you have sat with your friends around a bonfire at a wiener roast, you have probably felt your face growing hot while your back remained cold. You know from your experiments that the heat could not have reached your face either by conduction or by convection currents. How, then, did it travel from the bonfire to you? It was transferred, in this case, by *radiation* (rā-di-ā′shŭn).

Heat energy comes to us from the sun in the same way. The sun's energy, called by scientists *radiant energy*, travels out from the sun in all directions. Some of this energy reaches the earth, and when it strikes objects on the earth, it is changed into heat. Have you never burned your feet on hot stones, sidewalks, or other objects that have been exposed to the sun on a hot summer's day? Radiant heat from the sun travels to the earth through the great space between the sun and the

earth in which there is no air. Heat travels slowly by conduction and by convection, but by radiation it travels at the tremendous speed of 186,000 miles per second.



How a hot-air furnace heats a house. What causes the convection currents indicated by the arrows?

Something to Do

Radiation cannot be fully explained in this book, but it is very interesting. Read about it in a book about heat.

WHY ARE LIGHT-COLOURED CLOTHES COOL?

One winter's day when the snow on the ground was thawing slightly, Jane hung a washing on the line. A few hours later, when she went to bring it into the house, she found that two handkerchiefs, one dark-coloured and the other light-coloured, had fallen on the snow. As she picked them up, she was puzzled to find that the light-coloured handkerchief came away easily, but the dark-coloured one stuck slightly to the snow, as if the snow beneath it had melted and then frozen again. What do you think might have happened? Which handkerchief do you think had absorbed the more heat from the sun's rays?

Jane's experience shows that dark-coloured surfaces absorb heat more readily than light-coloured surfaces. Light-coloured surfaces tend to reflect or throw back more heat than they absorb. During warm weather, therefore, you will be cooler in light-coloured than in dark-coloured clothes.

Review Questions and Exercises

1. How is heat transferred through a silver spoon that has been left in a cup of hot tea or coffee, or through a poker that has been used to stir up a fire?

2. Name three good conductors of heat and three good insulators.

3. Draw a labelled diagram of an experiment to learn whether or not water is a good conductor of heat.

4. Explain how woollen clothes keep us warm.

5. Describe how heat is transferred through a liquid such as water.

6. Draw a labelled diagram of an experiment to find out how heat is transferred through a gas.

7. Why does a down comforter make a warm covering?

8. Sometimes when we try to light a fire while the chimney is cold and damp, the fire smokes. Why?

9. How does heat from a fire in a stove reach the far corner of a room? How does the heat escape through the stove? What is set up in the air in the room?

10. When you stand facing an open fire, how does the heat that reaches your face travel to you?

Something to Do

Investigate the heating system of your school. Draw a diagram of the stove or furnace, and indicate by means of arrows the path travelled by the heat through the pipes and radiators (if there are any) and throughout your classroom. Find out how the dampers regulate the burning of the fire. This information will be useful to you in a later study.

FIRE! FIRE!

As you know, fire may be either a deadly enemy or a very helpful friend. To make fire serve useful purposes, we must know both how to produce it and how to control it. Fire can be produced only under certain conditions. As you read on, you will discover what conditions are necessary to make substances burn.

The pupils in this illustration are experimenting to discover whether air is necessary for burning.

IS AIR NECESSARY FOR BURNING?

Ruth was taking part in a Christmas pageant at school. Suddenly her sleeve brushed the flame of a nearby candle, and in a flash she was enveloped in fire. The teacher immediately snatched up a heavy blanket and wrapped Ruth up in it. The flames were extinguished, and Ruth's life was saved. How do you think the blanket helped to save Ruth's life?

Something to Do

1. Place two candles side by side in a quarter-inch of water in a saucer. Light the candles, and place a lamp chimney over them. What change do you observe in the burning of the candles? If the candles have been extinguished, relight them. Now hold the lamp chimney a short distance out of the water. How do the candles burn when the chimney is thus raised? A smoking splinter of wood, or a roll of paper or rag, will indicate the flow of air into the lower part of the chimney. Lower the chimney again, and place a card over the top. What happens to the flames? Why?

2. Attach a short piece of candle to a fairly stout wire. Light the candle, and lower it into a wide-mouthed glass jar. Cover

the top of the jar with a piece of cardboard. What change takes place in the way the candle burns?

By covering the lamp chimney in the first experiment and the glass jar in the second, you have treated the candle flames in exactly the same way as the teacher treated the flames when she wrapped Ruth in the blanket. You have prevented air from reaching them.

When you studied the heating system of your school (page 105), you no doubt observed that a fire in a stove or a furnace burns best when the lower draft is open and the upper draft is closed. Your latest experiments have shown you why—because, when the drafts are thus arranged, a current of air is admitted to the burning fuel.

WHAT IS IT IN AIR THAT PROMOTES BURNING?

Something to Do

Stand a candle in half an inch of water. Light it. Place a wide-mouthed glass jar, mouth down, over the candle. What happens to the water as the flame is extinguished?

The fact that, as the flame was gradually extinguished, the water rose in the glass jar indicates that the burning of the candle must have removed something from the air. Scientists have proved that this something is a gas called *oxygen.* Since the removal of the oxygen resulted in the flame being extinguished, oxygen must be the element in air that promotes burning.

Something to Do

Problem.—How can a supply of oxygen be prepared and studied?

Apparatus and Material.—A hard glass test-tube; a one-holed rubber stopper or a cork; a glass delivery tube with a rubber extension; two or three wide-mouthed glass bottles; a vessel of water; an alcohol lamp; an iron stand and clamp; potassium chlorate; manganese dioxide; a wooden splinter.

Repairing railroad tracks by oxy-acetylene welding. The great heat required to melt the steel is obtained by burning acetylene in a current of oxygen. (Canadian Pacific Railway photo)

Method.—Mix one teaspoonful of potassium chlorate and one-half teaspoonful of manganese dioxide. Arrange the apparatus as in the diagram on page 116. (Moisten the glass tube before inserting it into the rubber stopper in order to make it slip in more easily.) The open end of the test-tube should be a little lower than the other end. Spread the chemicals along the test-tube.

Before beginning to heat the chemicals, fill two or three wide-mouthed bottles with water, and set them, mouth down, in the vessel of water. Use the bottles to collect oxygen gas when it is generated.

Begin heating the chemicals carefully. Regulate the heat so that the gas does not come off too violently; a steady stream is better. After the gas has been escaping for about half a minute, collect gas by the method shown in the diagram.

NOTE.—When you are ready to discontinue collecting gas, be sure to withdraw the end of the rubber tube from the water before removing the heat from below the test-tube. If you neglect to do so, cold water will rush into the hot test-tube and break it.

The gas you have been collecting is oxygen. When you have a bottle full, hold a piece of glass over the mouth, and place the bottle, mouth up, on the table. Observe the colour of the gas. Insert a glowing splinter of wood into the bottle, and observe the results.

Observation.—Does oxygen burn? Does the glowing splinter of wood burst into flame when it is inserted into the bottle of oxygen?

Conclusion.—State what you have learned about oxygen in this experiment.

In this last experiment you will have observed that the glowing splinter burns more vigorously when it is thrust into a bottle of oxygen. What actually happens is that part of the wood combines with some of the oxygen. The gas oxygen readily combines with a number of substances. The process by which the combination takes place is known to scientists as *oxidation*. Burning is rapid oxidation. One of the products of oxidation is heat. Later experiments will reveal another product.

CAN WE FIND A GAS THAT EXTINGUISHES A FLAME?

Something to Do

Problem.—What effect has breathed air on limewater?

Method.—Prepare some limewater by putting a tablespoonful of lime in a quart sealer and half-filling the jar with water. Stir it well, and leave it to settle.

Pour a little of the *clear* solution into a test-tube or a small bottle. Blow your breath through the limewater, using a piece of glass or rubber tubing, a straw, or even a sheet of paper rolled into a small tube. Continue blowing for a minute or more. If your experiment is successful, the limewater will turn milky. What do you think caused the change in the limewater? Examine the test-tube closely. You should be able to see tiny white particles all through the liquid. It is these white particles that produce the milky appearance. What gas is present in exhaled air?

Since, according to scientists, carbon-dioxide is the only gas that will turn limewater milky, *carbon-dioxide* must be present in exhaled air. The method just described of distinguishing carbon-dioxide from other gases is known as the *limewater test.*

Something to Do

Problem.—Will carbon-dioxide put out a flame?

Apparatus and Material.—A splinter from a shingle; matches; limewater; rubber tubing; a small glass jar, or a small wide-mouthed bottle; a pan or a dish to hold water; cardboard.

Method.—Fill the jar with water. Cover the mouth of the jar with the cardboard, and invert it in a pan containing about an inch of water. Remove the cardboard. Using the tube, blow into the jar air that has been held in the lungs for some time. Continue to do this until the jar is full of gas. Cover the jar again, and set it upright on the table. Then light the wooden splinter, and thrust it into the jar. What happens? Does the splinter continue to burn?

Collecting air that has been held in the lungs for some time. Why does the air cause the water to come out of the bottle?

Since a burning splinter continues to burn in ordinary air, but is put out by exhaled air, it would appear that carbon-dioxide, which is present in breathed air, will not support burning. Scientists have proved this to be the case. This test, therefore, is frequently used to help to identify carbon-dioxide.

Something to Do

1. Here is another way to produce carbon-dioxide and experiment with it:

Fasten a fairly stiff wire to a china egg-cup or a small glass tumbler. Put a small quantity of baking powder in the egg-cup or tumbler, and place it in the bottom of a wide-mouthed glass jar. Pour boiling water over the baking powder, and immediately cover the glass jar with a piece of glass or cardboard. After a moment or two, try these tests:

(*a*) Insert a burning wooden splinter into the glass jar. What happens?

(*b*) When you feel sure that the glass jar is well filled with the gas being produced from the baking powder, carefully slide the cover to one side, and remove the egg-cup or tumbler. Pour a small quantity of clear limewater into the glass jar, and shake it. What change do you observe in the limewater in the glass jar?

These pupils are experimenting with carbon dioxide. One boy is heating water to pour into the baking powder in the egg-cup.

What two observations tell you that carbon-dioxide is produced when boiling water is added to baking powder? What colour is carbon-dioxide?

NOTE.—Baking soda and vinegar may be substituted for baking powder and hot water.

2. Prepare a bottle of carbon-dioxide by the method described in the preceding experiment. Pour the carbon-dioxide from your bottle over a lighted candle. It is heavier than air, and so can be poured as suggested. What happens to the candle flame?

Some fire extinguishers contain a supply of carbon-dioxide, under pressure, which may be used to put out a fire.

IS CARBON-DIOXIDE A PRODUCT OF BURNING?

When substances such as fuels burn, new substances are formed. To discover whether one of these new substances is carbon-dioxide, perform the following experiment.

Something to Do

Fasten a wire (or a string) to a candle. Light the candle, and lower it into a glass jar. Cover the top of the jar. When the candle flame is extinguished, carefully slide the cover to one side, and lift out the candle. Add a small quantity of clear limewater, replace the cover of the jar, and shake the contents. What does the limewater indicate was produced when the candle burned?

To be sure that the burning of the candle actually produced the carbon-dioxide found in the jar in the foregoing test, perform a *control* test. Pour a small quantity of limewater into a glass jar in which no burning has occurred. Shake the jar. Observe the results.

Fuels, such as wood, coal, kerosene, and gasoline, contain a substance called *carbon*. When these fuels burn, the carbon in them unites with oxygen in the air to form carbon-dioxide. Under certain conditions, however, another gas called carbon-monoxide is formed.

HOW IS YOUR BODY HEAT PRODUCED?

The sleigh-bells jingled pleasantly as the horses trotted along. Frequent and merry was the laughter of the boys and girls. Mary, John, and their classmates were enjoying a sleighing party. It was a cold night, and the moonlit landscape was blanketed deep in snow. But wrapped up in their heavy clothing, the boys and girls were warm and cosy. What was the source of the heat that kept them warm? What produces the heat that keeps your body warm?

In your body there is a process, called *respiration*, going on continually, regardless of whether you are awake or asleep. In this process, oxygen from the air you breathe in is carried in your blood stream from your lungs to the cells in all parts of your body. In the cells, the oxygen is used to break down food material by a process of slow oxidation. This produces heat and energy, somewhat as the burning of fuel furnishes heat and the power to do work. In the cells the process goes on slowly, and no flame is present. Respiration produces the heat that keeps your body warm and generates the energy you use to walk, talk, play ball, in fact to do everything you do. The "burning" of food in the cells leaves a waste product, carbon-dioxide, which the cells must get rid of. In plants this waste is "breathed" out mostly through the leaves. In many animals it is exhaled through the lungs. The exchange

An exciting moment in a hockey game. What is the source of all the energy used by hockey players? (Alexandra Studio photo)

of gases, commonly called breathing, is an aid to respiration, but it is not respiration. Respiration takes place in every live cell of all plants and animals. It takes place in the roots and stems as well as in the leaves of plants. It goes on in every part of your body, and not in your lungs alone.

Review Questions and Exercises

1. Briefly outline an experiment to prove that air is necessary for burning.

2. Which of the gases present in air promotes burning? Tell what you know about this gas.

3. How should the dampers or checks of a furnace or stove be regulated to make the fire burn? To hold the fire in check?

4. Define or explain the term *oxidation*.

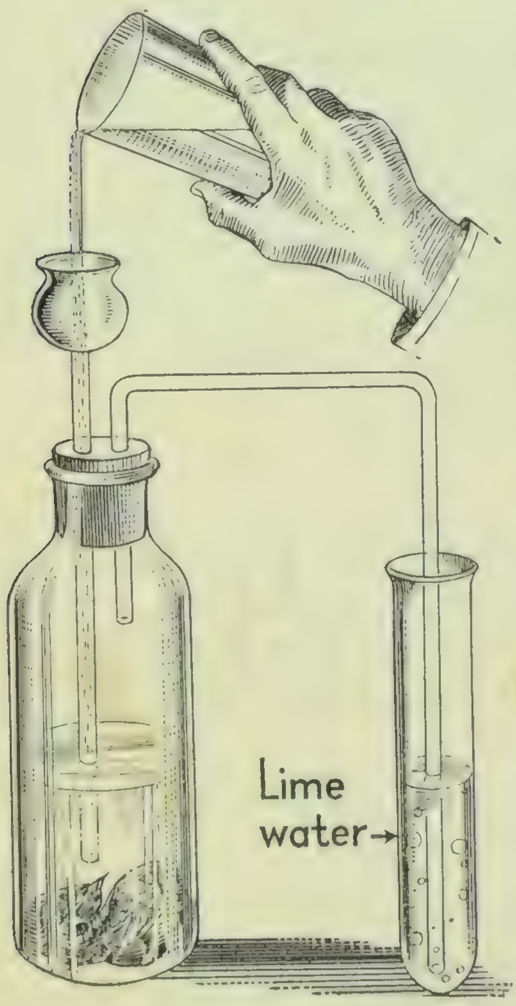
5. Compare *burning* and *respiration* with respect to (*a*) substances involved, (*b*) products resulting, (*c*) rapidity of action, and (*d*) locations in which each takes place.

6. Describe an experiment to find the effect of breathed air on limewater. What is there in breathed air that causes the change in limewater?

7. Explain a method of producing a supply of carbon-dioxide for study, using baking powder or soda.

8. Compare oxygen and carbon-dioxide with respect to (*a*) colour, and (*b*) effect upon a fire.

9. Why is respiration an important body process in both plants and animals? What are the products of respiration?



Do leaves give off carbon dioxide in the dark? Place lettuce or other green leaves in a bottle. Stopper the bottle, and place it in a dark cupboard for a day or two. Then set up apparatus as shown in the diagram. By means of water, as illustrated, force the air from the bottle into the limewater. What do the results of your experiment prove?

Problems to Solve

1. We sometimes cool our porridge by blowing our breath across it. We also warm our fingers by blowing on them. Explain.

2. Why will the parts of the iron framework of a building be held together more tightly if red-hot rivets are used than if cold rivets are used?

3. A cloth may be used to prevent you from burning your hands when removing a hot pan from a stove. Why?

4. When you get out of bed on a cold morning, why does the rug feel warmer to your feet than the floor does? (Remember that both the floor and the rug will be at the same temperature.)

5. When a housewife preserves fruit, she fills the fruit jars to the brim with hot fruit. Then she puts on an air-tight top. A few hours later she finds that there is an empty space between the top of the fruit and the top of the jar. Why?

6. Why does an earthen teapot keep tea warm longer than a silver pot? How does a woollen tea-cosy help to keep the tea warm?

7. Mary was drying dishes for her mother. The water was hot, and Mary noticed that some of the dishes were dry before she picked them up to dry them with her cloth. Where had the water on the dishes gone so quickly? Why?

8. Linemen stringing telephone wires during the summer must not stretch them too tightly. Why? Find other instances in which it is important for workmen to know that solids expand when heated.

9. When fire breaks out at an oil refinery, water is not used to extinguish it. Water spreads an oil fire. Instead of water, a foam mixture is often applied to the fire to smother it. What element is prevented by the foam mixture from reaching the fire, thereby causing the fire to go out?

10. Sometimes, after a clinker has been removed from a fire with the aid of a poker, the fuel becomes packed tightly and the fire burns very slowly. Why? The clinker itself sometimes forms an air-proof layer across the bottom of a fire, with the result that the fire is checked. Why?

Test your Knowledge

Rewrite the following sentences in your science note-book, filling in the blanks or selecting the words or phrases to make each correct.

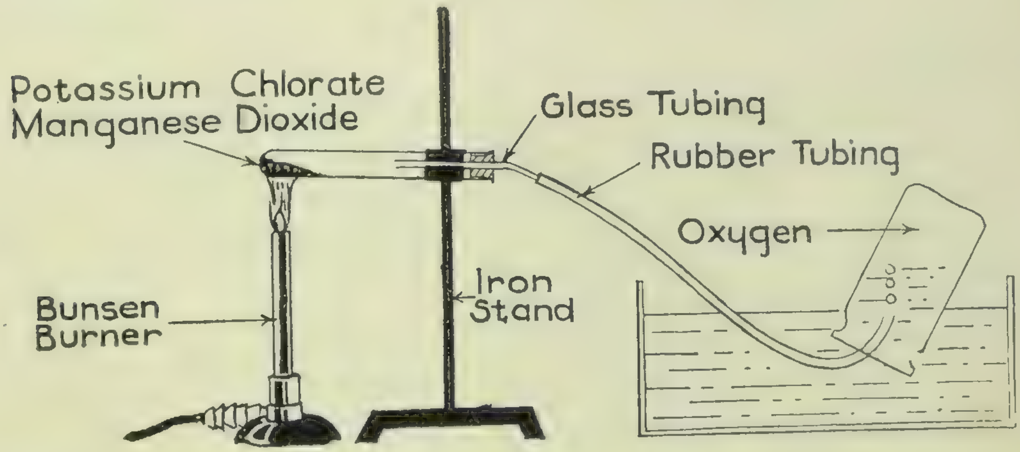
1. Heat is a form of ______.
2. Life in cold regions is ______ difficult than it is in warm parts of the world.
3. When a metal ball is heated, its volume is *increased, decreased, unchanged.*
4. As the temperature of water drops to the freezing point, the water first ______, then ______.
5. Ice is *heavier than, lighter than, the same weight as* water.
6. 25° F. is 7 degrees ______ than freezing.
7. Heat is transferred through a metal rod by *expansion, convection, conduction.*
8. Water is a ______ conductor of heat.
9. Storm windows help to keep a house warm because the ______ between them and the windows is a ______.

10. Thermometers are used to measure *the temperature of, the amount of heat in, the rate of expansion of* an object.

11. Heat is transferred through a liquid chiefly by ____

12. Heat changes solids to ______, and liquids to ______.

13. Heat energy from the sun travels to the earth by *convection, conduction, radiation.*



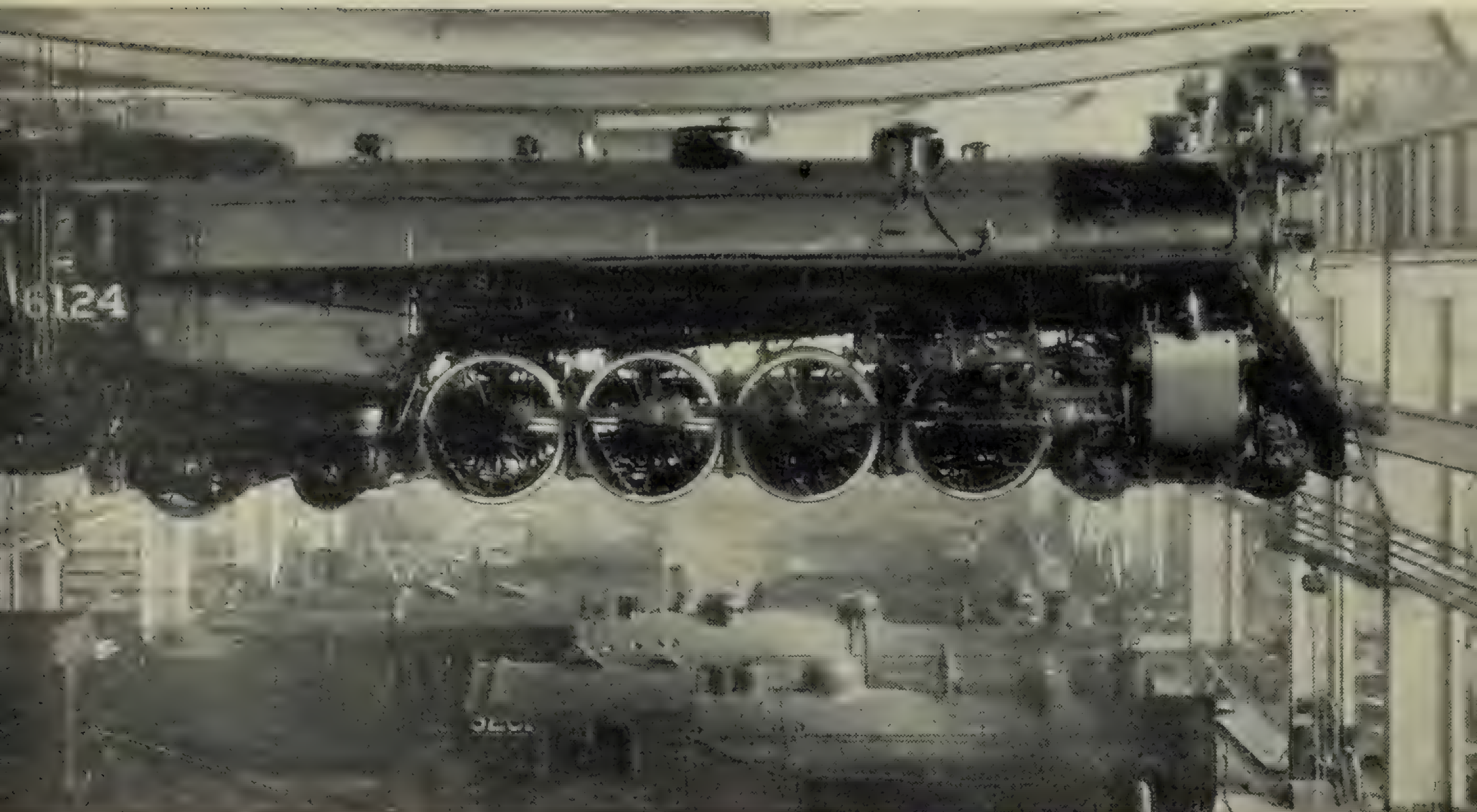
A diagram showing the apparatus required for the preparation of oxygen.

14. Six important steps in preparing a supply of oxygen are ______, ______, ______, ______, ______, and ______.

15. Oxygen *extinguishes, promotes, has no effect upon* a fire.

16. When fuels burn, a gas called ______ is produced.

17. Burning and respiration both include a process called ______. In both cases, ______ and ______ are produced.



Canadian National Railways

Give me a long enough pry, and a fulcrum on which to rest it, and I will move the world.

—ARCHIMEDES.

What cannot art and industry perform
When science plans the progress of their toil!

—BEATTIE.

CHAPTER

FIVE

CHAPTER 5

HOW WE LIGHTEN OUR WORK

From earliest times man has used machines to lighten his work. Many of our machines to-day are very complicated, but some of them are so simple that perhaps you do not even think of them as machines. Have you ever used a pry to help to move an automobile out of a mud-hole? Why does the pry make it easier to raise the car? What is a machine? Do you know that knives, forks, spoons, scissors, keys, hoes, and your own arms are all simple machines?

We use machines so commonly to-day that we can hardly picture the time when all work had to be done with the aid of only a few very simple machines. The work of building the pyramids some five thousand years ago, for example, was mostly done by hand. Huge blocks of stone were dragged over the ground on sledges pulled by gangs of slaves. The only way the Egyptians knew to raise a heavy block of stone, once they had dragged it to its destination, was to push poles under it and lift it by hand. Many men lifted the block while others pushed soil under it. Slowly and laboriously the blocks of stone were assembled and piled one upon the other, with great effort on the part of many men. How the workers must have toiled! Many years were required to build one pyramid.

To-day, buildings larger than the pyramids, dams of enormous size, and huge ships can be built in a comparatively short time and by relatively few men. Powerful trucks speedily transport the necessary materials. Huge power

These girls are demonstrating the progress that has been made in machines used in the kitchen. Each girl is mixing the materials for a cake. Which girl is being helped most by a machine, and which least?

shovels dig whatever excavations are required. Giant derricks swing great steel girders into place swiftly and easily. Many other machines, some large and some small, are used by builders to speed and lighten their work.

You may be surprised to learn that most of the machines that we use so widely to-day were invented within the last hundred or hundred and fifty years. The following list shows the date on which each of the machines and processes listed was invented, or the date by which it had been improved to such a degree as to be useful.

1774—Watt's steam engine.
1786—Meickle's threshing machine.
1825—Stephenson's railway locomotive.
1831—McCormick's grain reaper (forerunner of the binder).
1844—Howe's sewing machine.
1860—The first working gas engine.
1865—Bessemer's cheap method of producing steel.
1868—The first typewriter.
1876—Bell's telephone.
1878—Edison's electric light.
1884—The linotype machine, making possible rapid type-setting for printing.
1893—The automobile and motion pictures.

1896—Marconi's wireless telegraph (forerunner of the radio).
1903—The Wright brothers' aeroplane.
1928—The first television broadcast.

If you pause to consider how much of our work is done by machines to-day, you will realize what great changes they have brought about in our way of living.

The efficient transportation machines of to-day make possible the rapid exchange of commodities amongst the peoples of the world. How does this affect our mode of living?

THE "AGE OF MACHINES"

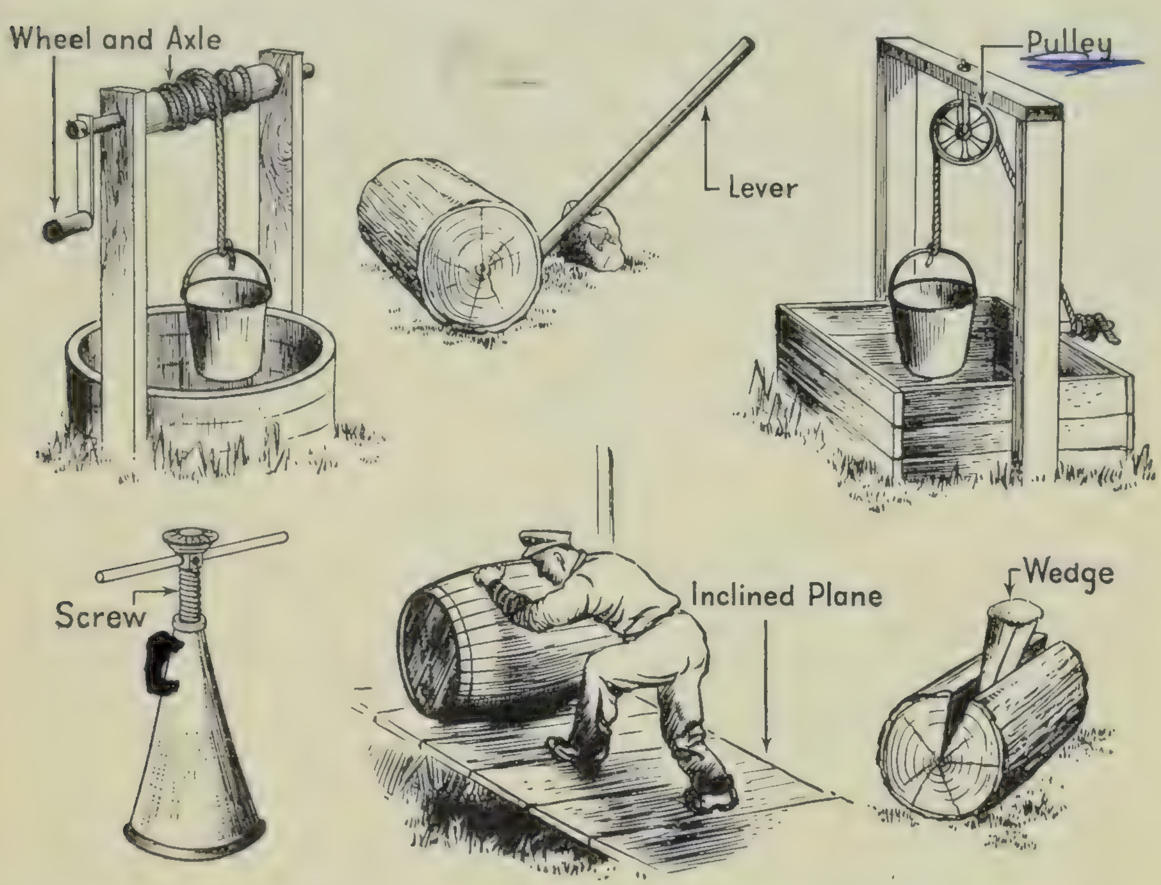
By the use of machines man is able to apply his energy to better advantage, and also to make use of energy from other sources such as waterfalls, wind, steam, and gasoline. Machines have made possible manufacturing on a large scale; rapid transportation by land, sea, and air; the building of immense buildings and great cities; and the many labour-saving devices that have added so greatly to the leisure and comfort of the people of to-day. Almost everything we wear and use is made by machines. We can now perform many kinds of work with machines that would be impossible without them. For example, we could hardly farm a section of land, as we know farming to-day, without the use of machinery.

You, yourself, use many machines each day. When you raise the flag at school, you use a common machine, the pulley. When you sharpen your pencil or cut your meat, you use another common machine, the wedge.

So widespread has the use of machines become that we sometimes call the present the *Age of Machines*.

A MACHINE CANNOT PERFORM WORK BY ITSELF.

An egg-beater, an automobile, a printing press, or a screwdriver cannot perform work unless a force or effort is exerted upon it. In the case of the smaller, simpler machines, our own muscular effort is sufficient. But the larger the machine, the greater is the force required to put it to work. To secure work from a plough, a windmill, an electric motor, a locomotive,



Examples of the six types of simple machines (see page 122). Name another example of each type.

or a gasoline engine requires the force or power of a team of horses, of the wind, of a powerful electric current, of expanding steam, or of exploding gas.

But force or power alone is not sufficient to operate machines. ~~Man invented~~ and improved these modern servants, and man does the thinking required to put them to work. We can use machines for destructive purposes, as in war, or

Machines like this road-grading outfit help man to modify and improve his environment. What simple machine is the man on the grader grasping with his left hand? What simple machine is the man on the tractor using with his left hand?

we can use them to increase our comfort, convenience, and safety, and to improve our health. Should we not make every effort to see to it that machines are used only to improve our environment, so that year by year the world may become a better place in which to live?

THE SIX SIMPLE MACHINES

Every tool, no matter how simple, is a machine. The *lever,* the *inclined plane* (a sloping surface used to make work easier), the *screw,* the *pulley,* the *wedge,* and the *wheel and axle* (a wheel or a part of a wheel fastened securely to an axle or rod) are sometimes called the *six simple machines.* The more complicated machines—for example, the bicycle, the printing press, the automobile, the tractor, the binder, the locomotive, and the sewing machine—are all constructed by combining two or more of the simple machines. Study the illustration on page 121; it will help you to recognize examples of the six simple machines when you see them.

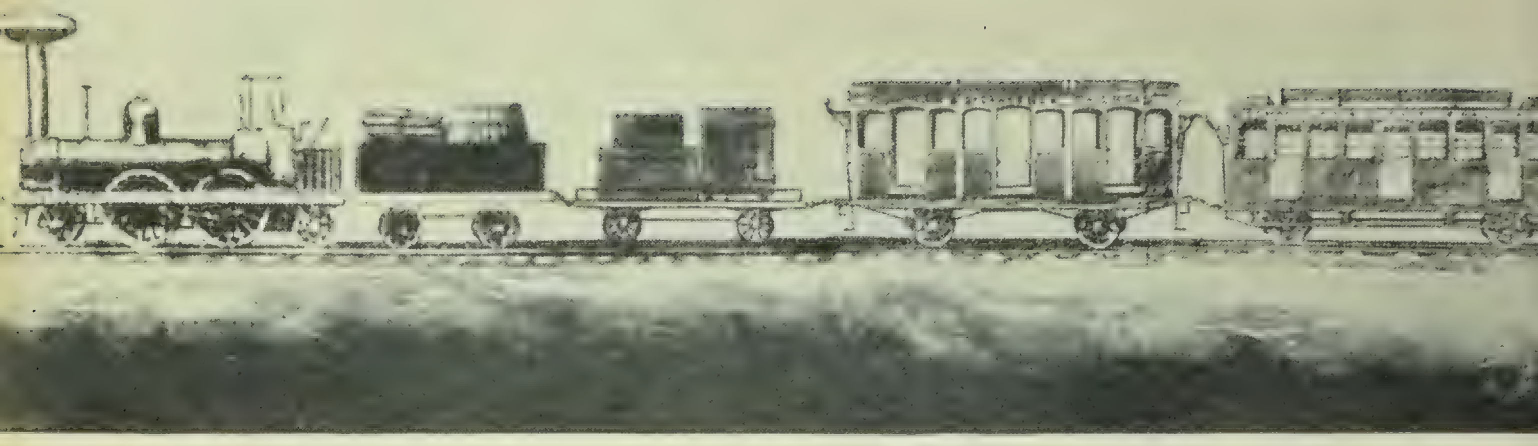
Many common tools are simple machines or combinations of them. The man in the illustration on the left is boring a hole in a sugar maple tree. The tool he is using consists of two simple machines: a wheel and axle (in his hands) and a screw (the bit boring into the tree). Pulleys are used to raise the sails of the sailing ship shown in the foreground of the illustration on the right. (Canadian National Railways photos)

These six machines, or combinations of them, help us to do certain kinds of work more speedily and accurately than we could do it without them, to move large weights with a small force, or to exert a force in one direction is such a way as to move an object in another direction. Make a list of examples of ways in which the use of machines makes work easier.

GEORGE STEPHENSON

Less than a hundred and fifty years ago there were no trains as we know them to-day. The first locomotive to draw goods and passengers made its first run in 1825. It was built by an Englishman named George Stephenson.

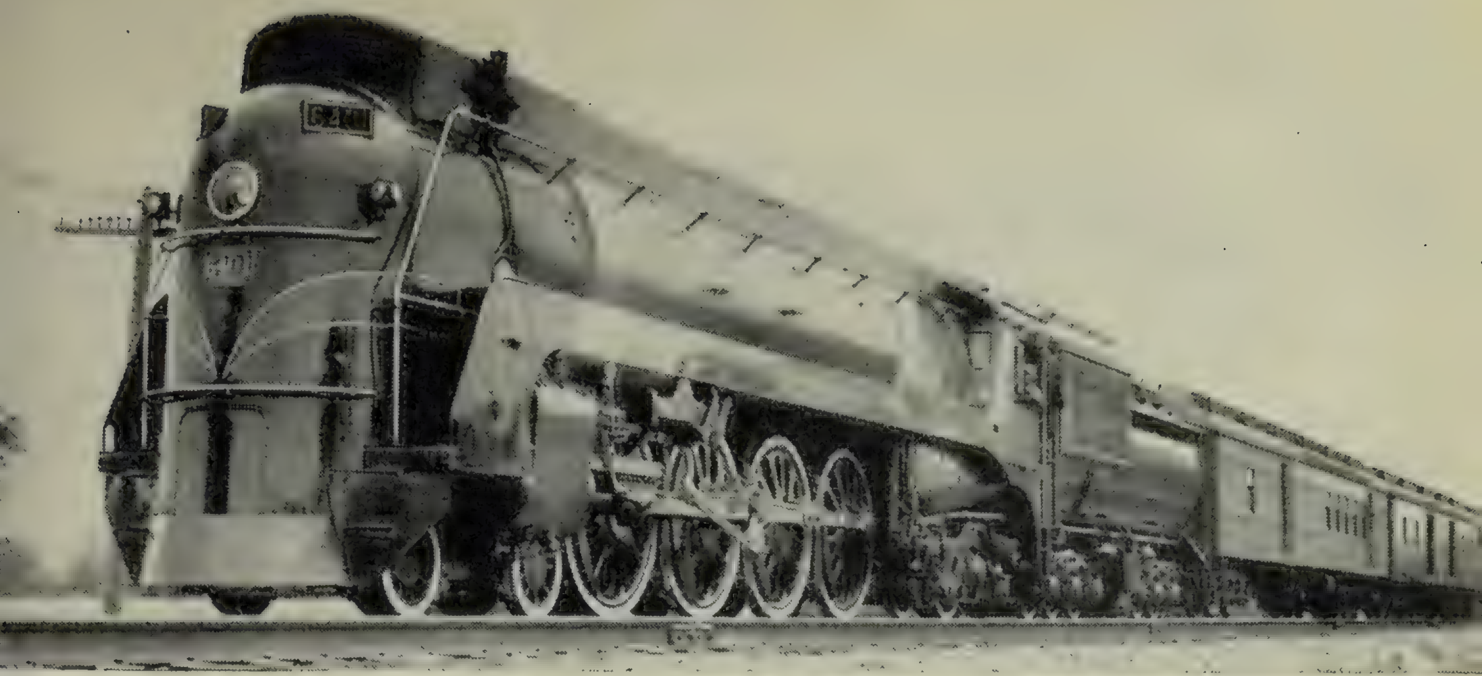
Stephenson was born in 1781. At fourteen years of age, he was helping his father to operate an engine that pumped water from a coal mine near Newcastle, England. The steam engines of those days were stationary. At twenty-one,



The first steam railway train in Canada, 1837. Compare the locomotive and cars with those of the modern train illustrated on the opposite page. (Dept. of Trade and Commerce photo)

Stephenson became an engineer, operating an engine that drew coal cars up from a mine. In some mines, the coal cars were hauled by horses along wooden or iron plates, which served as rails. Several unsuccessful attempts had been made to construct a moving engine, or locomotive, that would run along the road or on rails, pulling cars after it. Stephenson determined to succeed where others had failed, and with this object in view, he studied engines and experimented with their construction and operation. One of his early engines hauled thirty-four cars, carrying freight and passengers, at a speed of from four to six miles per hour. Finally, in 1829, after overcoming many difficulties, he built an engine, called the "Rocket," that averaged fifteen miles per hour — a remarkable speed for those days. With this locomotive he won a prize of $2500 in a contest in England.

At first, many people objected to the new railways. They disliked their noise and smoke, and were afraid of their speed. But as trains became increasingly successful, people used them more and more. George Stephenson was busy for many years building railways, and soon became known the world over for his knowledge of steam locomotives and for his work in improving them. Before he died in 1848, he had definitely laid the foundation of our modern railway systems. Through hard work and perseverance, he had made an outstanding contribution to speedy, safe, and economical rail transportation.



This powerful locomotive is a striking example of a huge modern machine. It is built on a streamlining plan, has power to haul as many as sixteen passenger cars averaging eighty tons each, and is capable of reaching a speed of a hundred miles an hour. The engine and its tender weigh six hundred and sixty-four thousand pounds. The big drive wheels are each six feet five inches in diameter. (Canadian National Railways photo)

HOW DO LEVERS MAKE WORK EASIER?

Every time you use a hammer to pull a nail, or a pair of scissors to cut cloth, or a shovel to remove snow, you are employing a lever to make your work easier. The lever is one of the most widely used simple machines. What is a lever? How does a lever lighten our work?

Something to Do

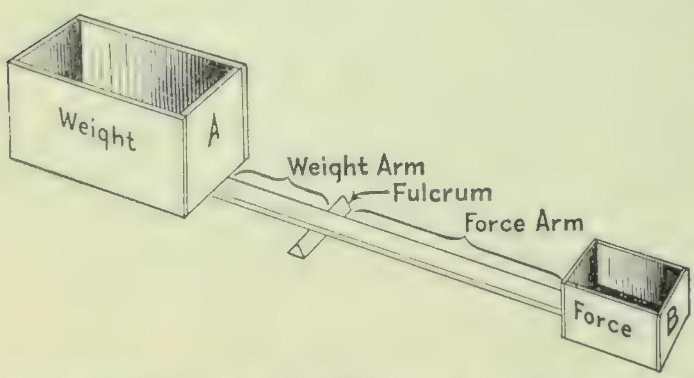
Problem.—When does a lever make work easier?

Apparatus and Material.—A box about the size of an apple box; a smaller box; a wooden bar about four feet long; several books to use as weights as described below; a three-cornered block of wood about four inches long; a bottle or tin can about the size of a pint fruit jar to use as a measure; dry sand (or soil).

NOTE.—Books may be used as weights in place of measures of sand, in which case a small platform can be substituted for the small box. *Plan your apparatus and experiment with the materials you have readily at hand.* A resourceful pupil will not hesitate to attempt an experiment just because the particular apparatus described is not available. He will find substitutes that will serve equally well.

Method.—Arrange your apparatus as illustrated on this page. Place five or six books about the size of this book in the end of the large box marked "A" in the diagram to make the box heavier.

Place the three-cornered block of wood, which we shall call the *fulcrum* (ful′krum), one foot from the large box. Using the bottle or tin can as a measure, pour sand into the smaller box, "B," until its weight raises the end of the large box. Keep a careful record of the quantity of sand required. Move the fulcrum to a position two feet from the large box, and again determine the quantity of sand required. Continue experimenting with the fulcrum at various distances from the large box: three feet from the large box, six inches from the large box, etc. Keep a careful record of the quantity of sand required in each case to raise the large box.



An experiment to learn how a lever makes work easier.

Continue experimenting until you can answer the questions asked on page 127 under the heading *Observation.*

Before discussing your findings, you must understand certain terms that are commonly used with reference to a lever:

1. A *lever* is any rigid rod or bar arranged to turn about a fixed point. In this case, the lever is your wooden bar.

2. The *fulcrum* is the fixed point; in this case, your three-cornered block of wood.

3. The weight to be lifted, the object to be moved, or the resistance to be overcome is called the *weight* or the *resistance.* In your experiment, the weight or resistance is the end "A" of the large box.

4. The push or pull to overcome the resistance or lift the weight is called the *force* or *effort,* which in this case is the weight of the measurefuls of sand.

5. The *weight arm* is the part of the lever between the weight and the fulcrum.

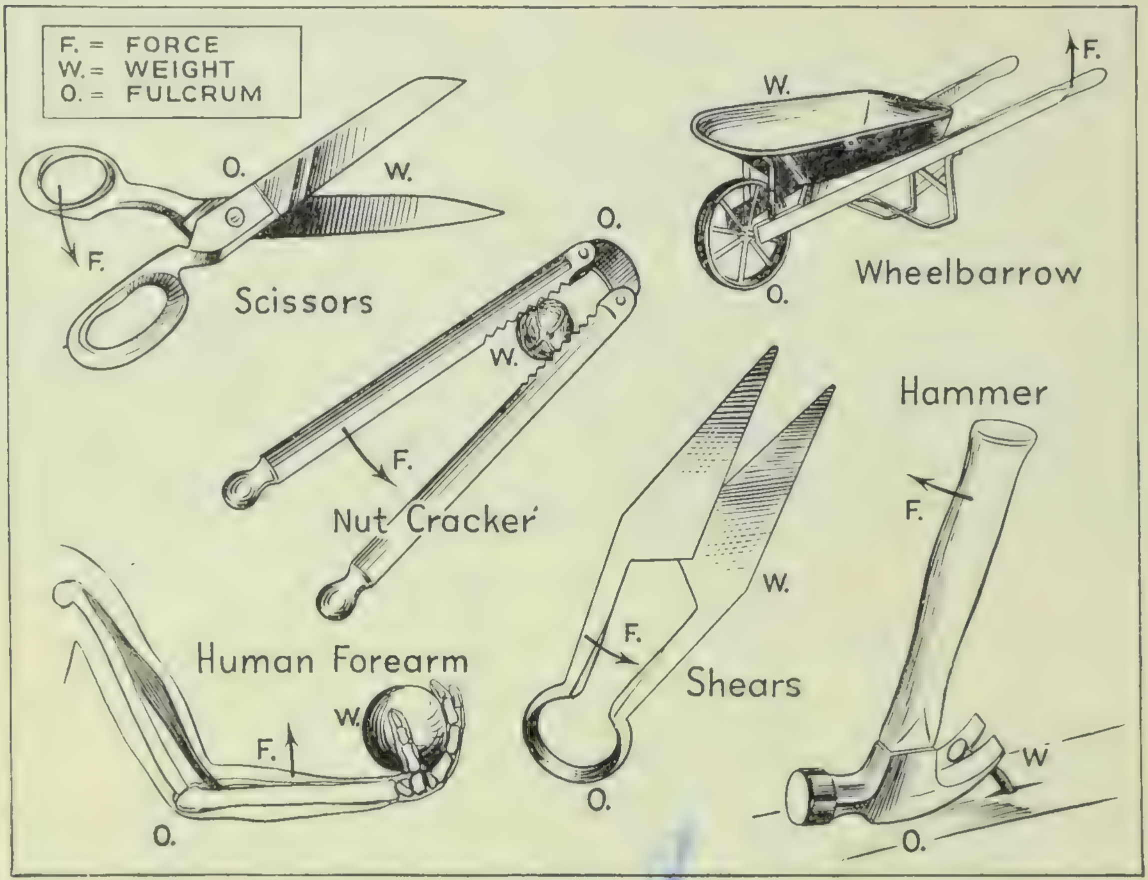
The fisherman is using a lever to "land" his fish. The guide in the canoe is using another lever. What is it? (Canadian Pacific Railway photo)

6. The *force arm* is the part of the lever between the point where the force is applied and the fulcrum.

Observation.—Is it easier to raise the "A" end of the large box by means of the lever than to lift it by hand? Is it easier or more difficult to raise the weight (the "A" end of the large box) when the fulcrum is nearer to the weight than to the point where the force is applied? Does the force required to raise the weight increase or decrease as the fulcrum is moved farther away from the weight? When the force required to raise the weight is small, is the force arm or the weight arm the longer? As the force required becomes less as the fulcrum is moved nearer to the weight, does the force arm become longer or shorter in comparison with the length of the weight arm? When the fulcrum is near the weight, do you think the force required is greater or less than the weight to be lifted?

Conclusion.—Upon what does the force required to lift a weight by means of a lever depend? When the force required is less than the weight, how does the length of the force arm compare with the length of the weight arm?

Test the truth of your conclusion by (1) cracking a walnut, first by pressing it between your two hands (with the fingers interlocked), then by using a nutcracker; (2) pulling a nail, first with your fingers, then with a hammer; (3) raising a large stone,



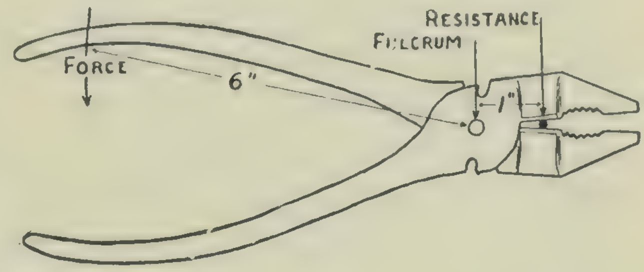
Some common examples of levers. Can you point out the force arm and the weight arm in each case? Look for other examples of levers and find the force arm and the weight arm in each.

first with your hands, then with a crow-bar. Compare the two methods in each case. Notice that in every instance the machine affords an advantage because it is a lever in which the force arm is longer than the weight arm.

The advantage to be gained by using a lever in most cases is that heavy weights may be lifted by relatively small forces. We have found, from the preceding experiment, that the closer the fulcrum is placed to the weight, the smaller will be the force required to lift the weight. In other words, the more the length of the force arm exceeds the length of the weight arm, the greater is the advantage to be gained by using a lever.

In the case of the lever you used in your experiment, the fulcrum is between the force and the weight. Common examples of this class of lever are a crow-bar and a block, scissors,

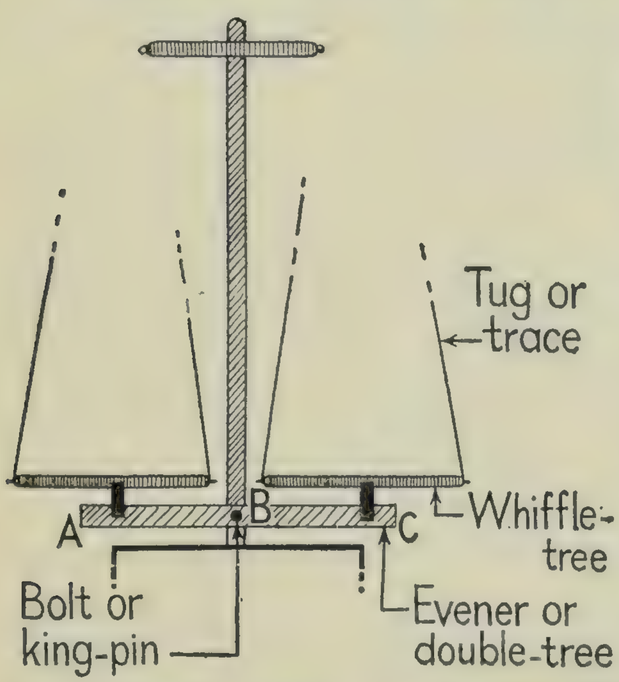
and pliers. But all levers are not like these. In some levers, the fulcrum is at one end, with the weight between it and the force, as in nut-crackers, the oar of a boat, a bottle-opener, and a wheelbarrow. In others, the fulcrum is at one end, with the force between it and the weight, as in a pair of sugar-tongs, a derrick, and your knife and fork.



If the wire offers a resistance of one hundred and eighty pounds, a force of only thirty pounds must be exerted to cut the wire.

HOW IS THE WORK OF PULLING A WAGON EQUALIZED FOR TWO HORSES IN A TEAM?

When the horses in a team are of equal weight and strength, each should pull an equal share of the load. How can the driver make sure that the work of both horses will be equalized?



Two horses pulling a wagon. The evener is a lever. A is the weight—the pull of one horse. B is the fulcrum. C is the force—the pull of the second horse. How must the length of AB compare with the length of BC in order to equalize the weight that each horse must pull.

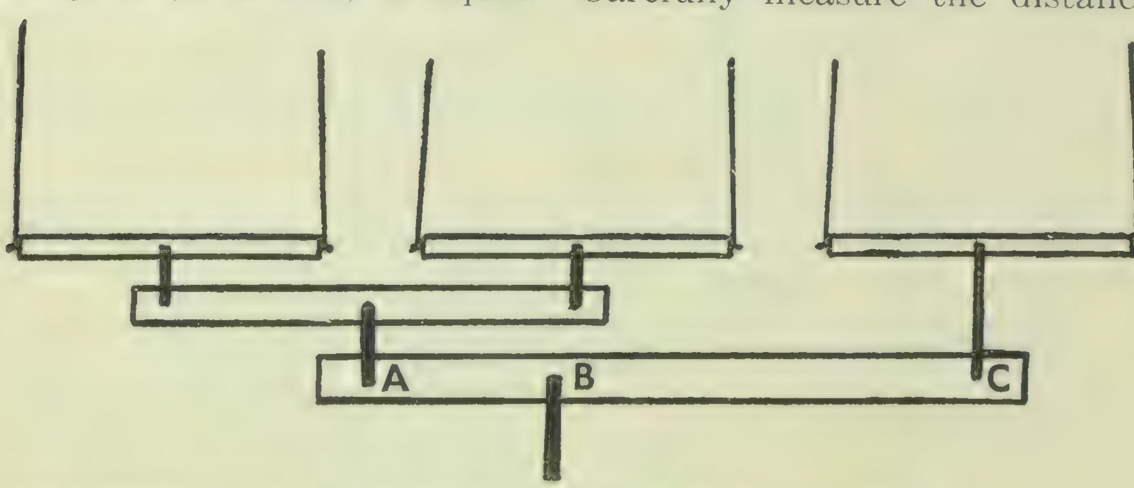
Something to Do

1. Study the diagram on the left to learn how the horses pull the wagon. The *evener* or *double-tree* is the part of the wagon in which we are chiefly interested in this discussion, since it is really a lever.

2. Perform the following experiment.

Problem.—How should the evener of a wagon be adjusted so that each horse pulls an equal share of the load?

Method.—Devise a way of suspending a yardstick or a lath at the centre so that it balances *exactly.* Provide two equal weights (any convenient objects) with loops of thread or fine wire by which to suspend them from the lever (the yardstick or lath). Let the weights represent the two horses. Suspend one weight near one end of the lever. Suspend the other weight on the other end of the lever, and move it back and forth until the lever is balanced, or in other words, until the pull of the two weights (or horses) is equal. Carefully measure the distance



This arrangement is used for three horses. Each horse pulls an equal share of the load. Why must the length BC be twice the length AB?

from the fulcrum to each weight. To be sure you are not jumping to conclusions or securing incorrect results, repeat the experiment several times, and calculate the average result.

Observation.—When the pull of the weights is equally balanced, how does the distance from the fulcrum to one weight compare with the distance from the fulcrum to the other?

Conclusion.—Where should the hole for the bolt (or king-pin, see diagram, page 129), by which the evener is attached to the wagon, be bored in the evener? If it is bored a little to one side of centre, will the horse on the short side have to pull more or less of the load than the other horse? It is important to place the hole correctly.

Review Questions and Exercises

1. Compare the work expended in washing clothes, preparing meals, cleaning house, or making a dress or suit of clothes by

hand with the work involved in doing the same operation with the help of the machines that are available to-day.

2. How are machines used to build roads, canals, dug-outs on farms, railways, buildings? How do machines help us to transport goods and people?

3. Make a list of machines that are operated by water power, by steam power, by electrical power, by wind power, by the power of exploding gasoline, by animal power, and by hand power.

4. Draw a diagram to represent a simple lever. Mark on your diagram: (*a*) the fulcrum, (*b*) the point at which and the direction in which the force is applied, (*c*) the point at which the weight rests on the lever, (*d*) the weight arm, (*e*) the force arm.

5. Briefly outline an experiment to find where to place the fulcrum to make it possible to raise a weight more easily by means of a lever.

6. Will more or less force be required to raise a weight when the force arm of a lever is long in comparison with the length of the weight arm than when it is short?

7. John and Tom were moving a large stone. First they pried it up with a long iron bar; then they pushed it up a plank into their wagon. What two simple machines did they use?

8. The evener or double-tree of a wagon is a lever. What acts as the fulcrum? the weight? the force? Where should the hole for the king-pin be bored in the evener to ensure that each horse will pull an equal share of the load?

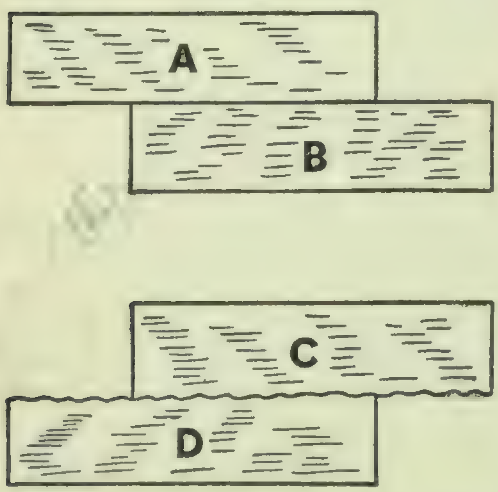
9. Outline an experiment which will show that the answer you have given to the second part of question 8 is correct.

HOW DO WHEELS HELP US TO MOVE HEAVY LOADS?

Most small boys have had the experience of sitting on one foot in a coaster wagon and pushing themselves swiftly along with the other foot. Could a boy propel himself in the same way in a sleigh during the summer months? Why not? A farmer's horses can easily haul an eighty-bushel load of wheat to the elevator in a sleigh when there is snow on the ground, but they could not move the load in a sleigh on the bare ground. A sleigh slips along readily over a snowy surface because each

runner is able to make a smooth track for itself in the snow. But on bare ground the runners stick and are held back by an invisible force known as *friction* (frĭk′shun). Any force that retards or prevents the motion of one body on another is called friction.

Friction is caused by two surfaces rubbing together. Even surfaces that appear smooth have roughnesses or projections on them, which are so tiny that they can be seen only under a microscope. When two surfaces are rubbed together, the projections on one surface fit in between the projections on the other. This tends to prevent the one surface from sliding easily over the other. The smoother the surfaces the less friction there will be, and the rougher the surfaces the more friction.



Which will be easier, to slide block A over block B, or to slide block C over block D? Why? In which case will there be the more friction? State one cause of friction.

Two kinds of friction can readily be distinguished: *sliding friction,* such as that which is set up between the floor and a box that is being dragged over it, and *rolling friction,* such as that which occurs between the rim of a moving wheel and the ground. Rolling friction is less than sliding friction, as you can learn by performing the following experiments.

Something to Do

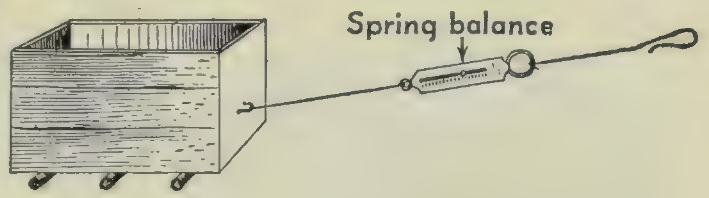
1. Attach a hook or ring firmly near the bottom of one end of an apple box. Connect a spring balance to the hook, using about a foot of light rope or cord. Attach another length of rope to the other end of the spring balance, and tie a loop in the end of the rope. Place several books or other objects in the box to give it weight.

Then proceed as follows:

(*a*) By means of the loop in the cord attached to the spring balance, drag the box over the floor or the top of a suitable table. Keep a record of the pounds of effort or force required. This will be a measure of the sliding friction between the box and the floor or table top.

(*b*) Place several equal-sized marbles under the box, and again record the pounds of effort or force required to move the box. The result will demonstrate clearly how ball bearings reduce friction by changing sliding friction into rolling friction.

(*c*) Place several lengths of broom handle (or other convenient rollers) under the box, and measure the effort. This will illustrate how roller bearings reduce friction.



Apparatus for an experiment to compare rolling friction with sliding friction.

(*d*) Attach wheels (cut from a board with a fret saw) or large spools to the ends of the box, and again measure the effort required to pull the box along. Explain how wheels reduce friction.

NOTE.—If a spring balance is not available, the pull or effort required to move the box in (*a*) in comparison with the effort necessary in (*b*), (*c*), and (*d*) can be estimated as "more," "the same," or "less," and the advantage of ball and roller bearings and wheels can thus be demonstrated.

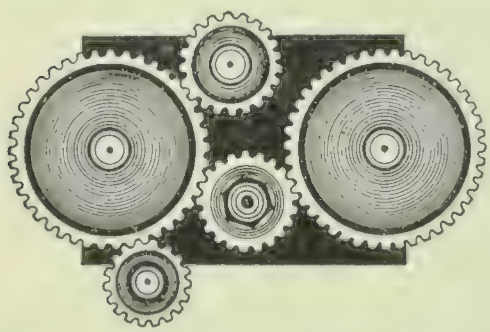
2. Rub two smooth boards together. Then grease or soap the surfaces, and rub again. In which case is there less friction?

3. Experiment with a machine that you have at home, for example, a lawn mower. Compare the ease with which it operates when well oiled with its operation when it lacks oil.

Wheels make it easier to move heavy loads by helping to overcome friction. They help to overcome friction because: (1) only a small part of each wheel comes in contact with the road; (2) they reduce sliding friction to rolling friction; (3) the surfaces of the axle and of the inside of the hub can be made quite smooth, so that one slides easily over the other; (4) the axle can be covered with grease or heavy oil. The

grease spreads out in a film, which separates the axle and the inside of the hub so that the two surfaces do not rub together. If the axles of a wagon are not kept well greased, friction is increased, and the wagon becomes harder to pull.

At one time, people had no wheels. Heavy loads were transported on sledges that were pulled by slaves. Then it was discovered that the load could be moved more easily if rollers were placed under the sledge. As one group of slaves pulled the load along, another put wooden rollers underneath the sledge; and as soon as the sledge had been pulled over a roller, the roller was picked up and placed under the sledge again. The first wheels were possibly slices cut from a roller or a log. Gradually wheels were improved until the efficient wheel of the present day was produced. Now we have a great variety of wheels serving a great variety of purposes; consider, for instance, the different types of wheels used in bicycles, automobiles, railway equipment, agricultural implements, wagons, and machines of many other types.



Wheels may be used to move other wheels. Notches are cut in the rims of the wheels to prevent slipping. Such wheels or combinations are known as *gears.*

We have learned by experiment that roller bearings and ball bearings also reduce friction. In many machines, steel balls, held in place in a case or "cage," (ball bearings) are used to separate moving parts and thus reduce friction. Steel rollers (roller bearings) are used in a similar way. Friction in ball and roller bearings is further reduced by keeping them well lubricated, that is, covered with suitable oil or grease. Friction between two moving surfaces causes them to wear away. Lubrication, therefore, by reducing friction, helps to reduce wear. It pays to keep machines well oiled; oil is cheaper than machinery.

The first successful power aeroplane just as it left the ground on December 17, 1903. Compare this early flying machine with the modern types shown on pages 4 and 11. (Brown Brothers photo)

THE WRIGHT BROTHERS

While this book was being written, newspapers were reporting the launching of a huge seventy-ton aeroplane, capable of making a non-stop flight over the Atlantic Ocean and return. As we read about such great machines, and remember that the first successful aeroplane flight was made as late as 1903 and that it lasted only fifty-nine seconds, we marvel at the rapid progress that has been made in aerial navigation during recent years.

Two brothers, Wilbur and Orville Wright, were the first men to fly a plane successfully. Men before them had lost their lives in the attempt. The Wright brothers studied and experimented for many years. They watched kites in flight. They built gliders and tested them. Their greatest problem was to find a method of preventing the gliders, which were really aeroplanes without engines, from capsizing because of their inability to adjust themselves to quickly changing air currents. But the problem was finally solved, a gasoline engine and a propellor were designed and constructed, and other details were made ready for the test that was finally to prove successful. The first public test was made in 1908. From that date, machines that could fly had become an established fact.

The Wright brothers were true scientists. They read about the work of others. They experimented to learn new facts.

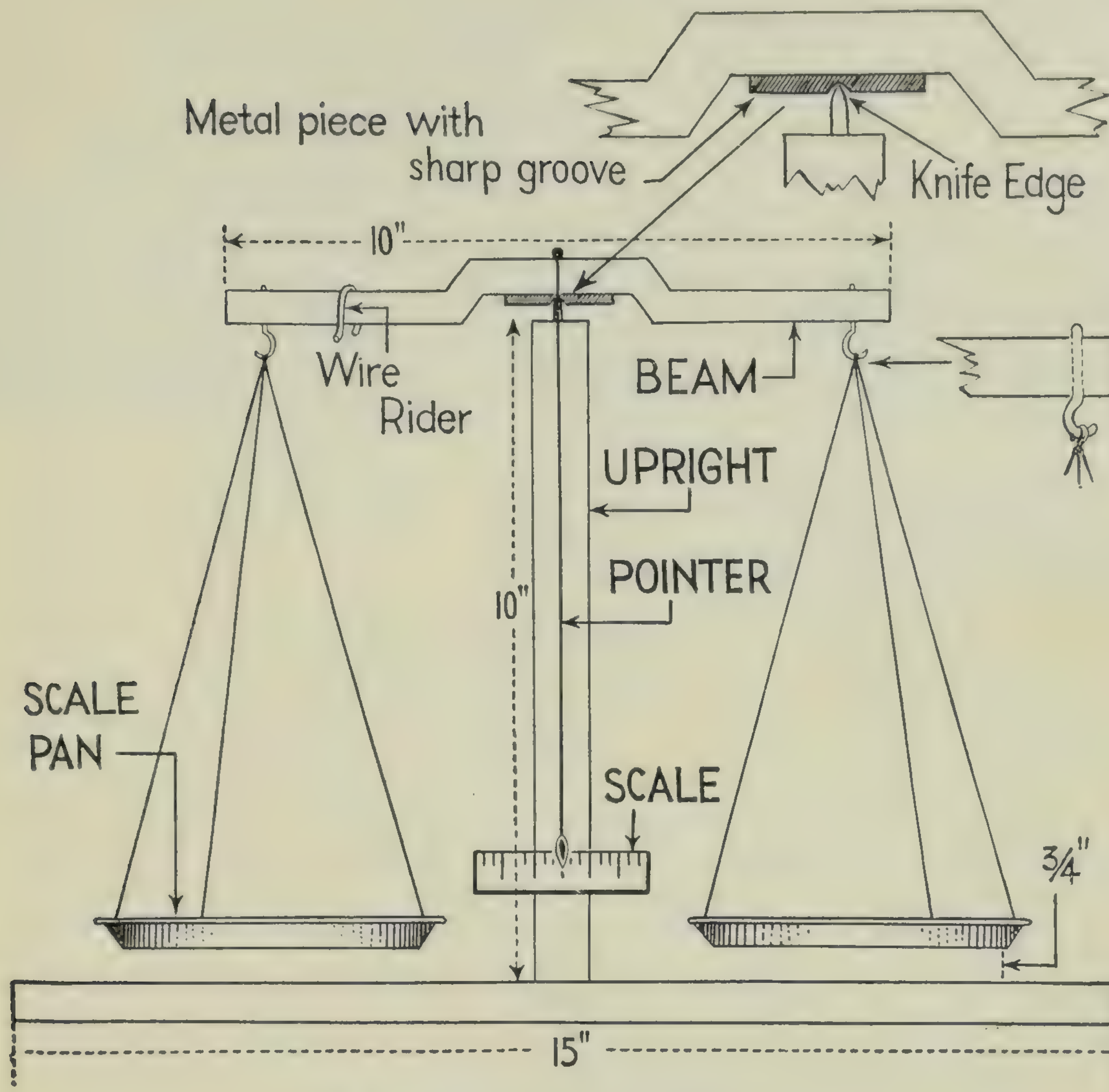
They thought carefully about what they read and observed. In the face of discouragement they worked patiently and advanced steadily towards their goal and final success. The result was the invention of a machine that, when rightly used, is of inestimable value to the world.

Review Questions and Exercises

1. Define or explain *friction.* How do irregularities on surfaces increase friction?
2. Why is a heavy box harder to drag over the floor than a lighter one? Give your answer in terms of friction.
3. When you make a slide at school, you can glide over it with little effort. Does the surface of the slide offer little or great resistance? Give a reason for your answer.
4. Outline several experiments to show that rolling friction is less than sliding friction.
5. Explain how wheels help to move heavy loads. Mention several ways.
6. Outline an experiment to show that lubricating moving surfaces with grease or oil reduces friction.

SCIENTISTS USE ACCURATE WEIGHING MACHINES.

It is important to know how to weigh things accurately. If you use too much or too little of a certain ingredient, your cake may be a failure. If a druggist makes a mistake in weighing the materials for a prescription, the result may prove fatal to the patient. In scientific work, it is particularly important to weigh materials accurately. Some balances used in scientific work are so delicate that air currents in the room influence them. These balances are enclosed in glass cases, and the final operations of weighing are performed with the cases closed. Weights obtained on such balances are accurate to an almost unbelievable degree. But the stouter balances or scales used for weighing heavy loads—of wheat or coal, for example—must also be accurate, if they are to be useful.



A home-made equal-arm balance.

A balance is not difficult to make if you follow directions and work carefully, but great accuracy is necessary to produce a satisfactory instrument.

Something to Do

Before you start to build your balance, study carefully every detail of the diagram on this page, and read the following instructions.

1. For a base, use a board $\frac{3}{4} \times 6 \times 15$ inches. In the centre of the top bore a hole three-eighths of an inch deep and just large enough in diameter to allow the *upright* (a length of broom handle) to fit in snugly.

The early settlers ploughed their fields with plough and ox-team very similar to the equipment shown in this illustration. Compare it with the modern tractor and plough shown on the opposite page. (Canadian Pacific Railway photo)

2. Saw a narrow slit one inch deep in the top of the upright. File, until it is sharp, one edge of a thin rectangular strip of hard metal, of the same width as the upright, and fasten it *securely*, sharp edge up, in the slit in the upright. This piece of metal is to be the *knife edge* that supports the beam; the harder and sharper it is, and the more securely it is fastened in place, the more accurate the balance will be. At the base of the upright, cut out a small piece to provide a flat surface to which to glue a *scale*, about two inches long, as indicated in the diagram. Finally, fasten the upright in the hole in the base by means of a small nail or screw inserted through the bottom.

3. From $\frac{1}{2}$-inch or $\frac{3}{4}$-inch wood, cut the *beam accurately*, as illustrated. In the *exact* centre of the under part fasten a short piece of hard metal, in the *exact* centre of which has been filed a sharp groove. About three-quarters of an inch from each end of the beam, and *exactly the same distance* from the centre of the groove, bore fine holes. Using two strips of wire *exactly* the same length, make two hooks, and insert one in each of the two holes. Fasten a fairly stiff wire *pointer* to the beam.

The base, upright, and beam may be stained or painted.

4. For *scale pans* use two jam-tin lids, as nearly alike as possible. In each lid, punch three holes at equal distances from one another. Cut two pieces of wire *exactly* the same length to make hooks for the attachment of the cords. Place the beam in position, and support one scale pan in position about half an

inch from the base. Estimate the required length of cord, and cut six pieces of fine cord *exactly* the same length. Hang the scale pans, making sure that each is level.

5. Arrange all parts as illustrated, and allow your balance to swing freely. If one side is too heavy, whittle a little wood from the heavy side of the beam, or hang a small U-shaped wire rider on the heavy side. When the scale is balanced, the pointer should point to the zero mark. Your balance is now ready to make weighings.

Machines make modern methods of farming possible. Find examples of two or three simple machines on this plough and tractor.

6. *A home-made set of weights*: Your balance will be more useful if you invent a set of weights, including $\frac{1}{2}$ oz., 1 oz., 2 oz., $\frac{1}{4}$ lb., $\frac{1}{2}$ lb., 1 lb., two 2 lb., and 5 lb. weights. Use small bags of sand for the $\frac{1}{4}$ lb. to 5 lb. weights and strips of tin or heavy wire for the smaller weights.

Practical Exercises with the Balance.—1. Which is heavier, sand or clay? Measure small equal volumes of dry sand and clay, and place them in the scale pans of your balance.

2. Practise weighing common objects, such as your pen-knife, a small bottle of ink, your watch, etc.

Review Questions and Exercises

1. To show how machines have improved our methods of working and increased the comfort and convenience of our lives, make the following comparisons:

(*a*) Compare transportation by travois, covered wagon, automobile, and aeroplane.

(*b*) Compare ploughing with a team of two oxen, with a team of from four to eight horses, and with a modern tractor.

How does a sewing machine make work easier? Find simple machines in the various parts of this larger machine. For example, the point of the needle is a form of wedge. (Singer Sewing Machine Co. photo)

(*c*) Compare the work of sewing with a needle and thread, a foot-power sewing machine, and an electrically operated machine.

(*d*) When you have information available, make other similar comparisons.

2. What machines are used: to split wood, to raise a pail of water from a well, to cut paper or cloth, to bend or cut wire, to pull a nail, to raise an automobile wheel to change a tire, to raise hay into a hayloft, to roll a barrel into a wagon, to tighten a nut, to dig a garden?

3. When you are using a pole and a stone to pry up one corner of a building, how would placing the stone nearer the building alter the force that you must exert? Why?

4. Sometimes when two horses are pulling a plough, one must travel on ground that is soft and difficult to walk on. What can be done to give this horse an advantage in the share of the load he must pull to offset his poor footing?

5. Why should moving parts of lawn mowers, sewing machines, automobiles, and other machines be kept well lubricated?

6. In constructing a balance for making weighings, why must the distance between the hooks from which the scale pans hang and the fulcrum be exactly the same in each case?

Something to Do

1. Make models or collect examples of the six simple machines.

2. Make a list of machines used in a grain elevator, in an automobile repair shop, in a dairy, or in a store. Visit one or more of these places to study machines.

3. Experiment with a plank and a block of firewood to find how one pupil can lift six pupils.

4. Make a trip around your home, your school, or your farm to look for machines that help to make work easier.

5. Experiment with a pair of scissors and a sheet of fairly stiff cardboard to discover where the cardboard should be placed between the blades to make the cutting easiest. Each half of the scissors is a lever. When the cutting is easiest, is the weight arm or the force arm the longer?

6. Look for examples of machines or parts of machines which are levers, inclined planes, wedges, screws, pulleys, or wheel-and-axles.

7. Watch workmen building a house. What machines do they use to dig the excavation, to mix cement for the foundation, to construct the framework, to haul the materials required, etc.?

8. Trace ways in which machines are used in producing a carload of wheat, transporting it to a flour mill, grinding it into flour, transporting the flour to the bakery, and, finally, producing loaves of bread for hungry people.

9. Ask a garage man or an implement dealer to show you roller or ball bearings. Perhaps he can show you exactly where bearings of these types are located in one or two machines.

10. Look for examples of wheels moving other wheels: by chains, as on a bicycle; by belts, as on sewing machines and threshers; by toothed edges, such as the gears on egg-beaters.

Test your Knowledge

Rewrite the following sentences in your science note-book, selecting the word or words that make each sentence correct:

1. People of several thousand years ago had to perform their work with the aid of *no machines, a few simple machines, many machines similar to those of to-day.*

2. The handles of a wheelbarrow are a good example of *an inclined plane, a pulley, a lever.*

3. A lever can be used to raise a weight with less force when the force arm is *longer than, the same length as, shorter than* the weight arm.

4. The fixed point about which a lever moves is called *the force, the fulcrum, the resistance.*

5. In a pair of scissors, *the resistance is between the force and the fulcrum, the force is applied between the weight and the fulcrum, the fulcrum is between the resistance and the force.*

6. When the hole for the bolt by which the evener is attached to the wagon is not bored in the centre of the evener, the horse pulling on the shorter side of the evener pulls *less than one-half, more than one-half, one-half* of the load.

7. Friction *makes easier, makes more difficult, has no effect upon* the motion of one surface against another.

8. Rolling friction is *greater than, the same as, less than* sliding friction.

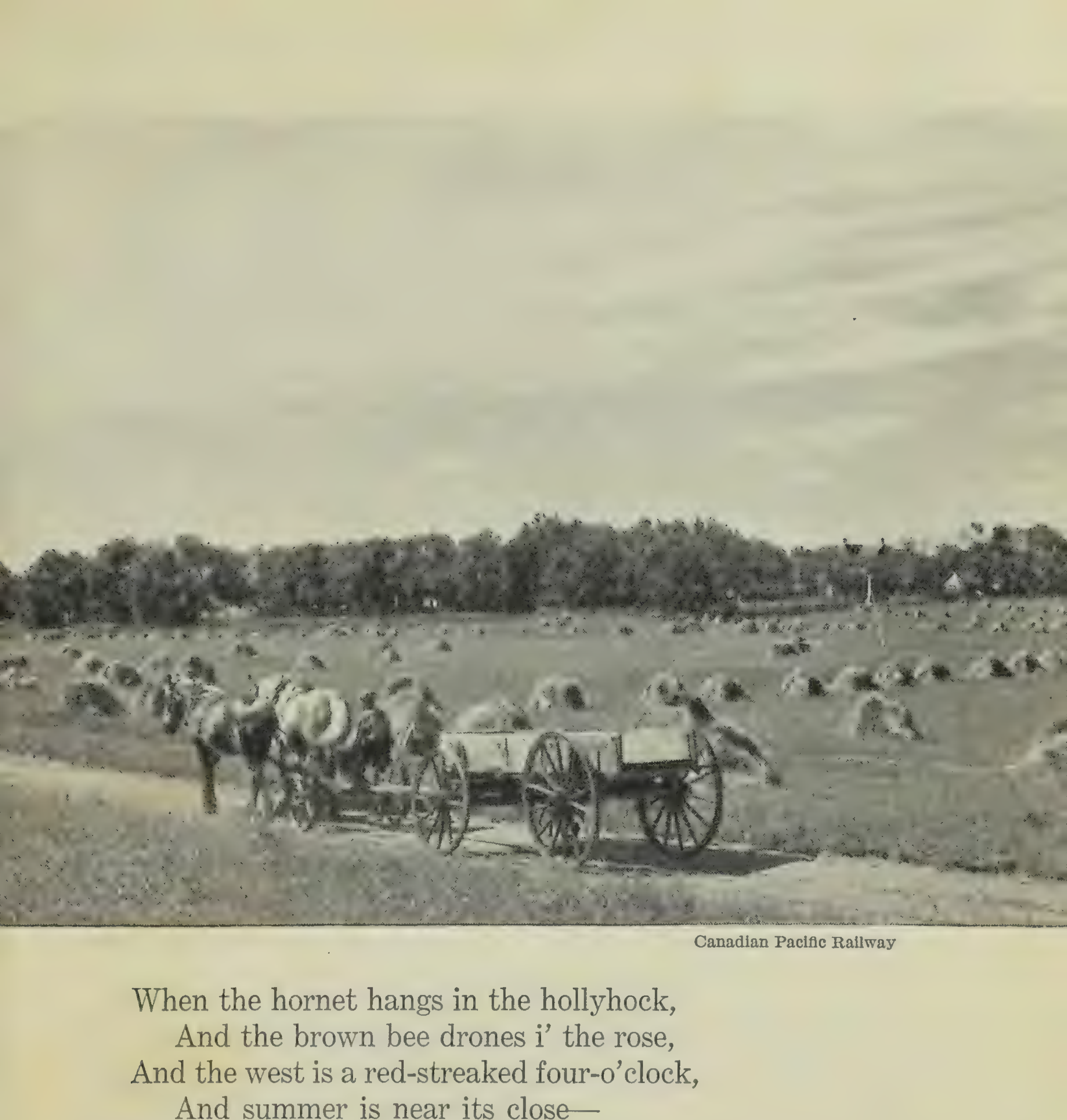
9. The chief reason why wheels make it easier to move heavy loads is that they *raise the load higher, are strongly built, help to reduce friction.*

10. Lubrication with grease or oil reduces friction by *making rubbing surfaces smoother, holding rubbing surfaces apart, making rubbing surfaces move more slowly.*

Tests on the Scientific Method and Attitude

1. Bob always believed that, when a lever is used to raise a weight, the force required is less than the weight to be lifted. One day he read that, if the fulcrum is placed in a certain position between the force and the weight, the force required is greater than the weight. In which of the following cases would he display a scientific attitude: (*a*) if he paid no attention to what he read, because he did not agree; (*b*) if he devised an experiment to investigate the statement; (*c*) if he read further in other books to check the statement made in the first book?

2. George was performing an experiment to find the force required to raise a weight by means of a pulley. He made one test and arrived at a conclusion. Later a classmate showed him that he had used a wrong weight in measuring the force required. Indicate in which of the following ways George did not use the scientific method in arriving at his conclusion: (*a*) he jumped at a conclusion with insufficient information; (*b*) he depended on one test only; (*c*) he was not careful to work accurately; (*d*) he allowed personal opinion to influence his judgment.



Canadian Pacific Railway

When the hornet hangs in the hollyhock,
 And the brown bee drones i' the rose,
And the west is a red-streaked four-o'clock,
 And summer is near its close—
It's—oh, for the gate, and the locust lane;
 And dusk, and dew, and home again!

—MADISON CAWEIN.

CHAPTER SIX

CHAPTER 6

THE FARM—A BUSINESS AND A HOME

What would happen if all the farmers went on strike? How would it affect you? If you should decide to be a farmer, what type of farming would you choose? Why? What problems would you have to consider in making your choice? What farms in your locality are the most valuable? Why?

Mr. White's class was discussing Canadian industries. The question of the importance of the various industries arose. Committees were organized to search for information. The following paragraphs tell briefly some of the facts the pupils discovered.

Of all industries, agriculture is admittedly the most important, not only because it supplies many of the essentials of life, but also because other industries are largely dependent upon it. The prime necessities—food and clothing—are secured mainly from the farm, either directly or in the form of raw materials for flour mills, meat-packing plants, fruit canneries, and woollen mills. From the transportation of wheat and other farm products, the railway systems derive much of their revenue. To supply the farmer with equipment, such as farm implements, large manufacturing plants have been developed. All these industries supply work and the means of living for many people.

Because so many Canadians depend for their existence, either directly or indirectly, upon the work of the farmer, agriculture is regarded as the basic industry of Canada. Wheat is one of Canada's chief sources of wealth. Most of

Wheat as far as the eye can see—a field in Western Canada. Grain-growing is still the leading type of farming in the Prairie Provinces. (Dept. of Agriculture photo)

her large crop is produced in Western Canada, where more than two-thirds of the population are engaged in farming.

Something to Do

1. "Agriculture is the industry that has to do with the cultivation of the soil for the purpose of growing crops to feed and clothe the people of the world." Discuss this statement. Does it cover all branches of agriculture? Which, if any, are not included?

2. Make a list of industries and businesses that depend in any way upon agriculture for their prosperity.

THERE ARE MANY TYPES OF FARMING.

Canada offers opportunities for many types of farming. In the Prairie Provinces, grain-growing is carried on most extensively. Modern machinery has made it possible to grow very large areas of crops. Wheat is the chief crop. The deep, rich prairie soil and the climatic conditions produce excellent bread-making wheat. In districts where the land is more hilly and broken by streams and wooded areas, conditions are more favourable for ranching. Great ranches are common in

Bee-hives on a farm where mixed farming is practised. The owner of this farm reduces his risk by having a number of sources of income, instead of only one. (Dept. of Agriculture photo)

Western Canada, and horses, cattle, and sheep are raised on a large scale.

As we go northward into what is known as the park country, there are more trees and also areas suited to growing good grass. There, less wheat and more of the coarse grains, such as oats, and potatoes are grown, and cattle, hogs, sheep, poultry, and bees are raised as well. Such a combination of enterprises is called *mixed farming*. Mixed farming is usually safer than straight grain-growing because it offers more sources of income and less likelihood of a total failure. It is the most common type of farming in Canada.

Dairying is profitable in districts where good water, pasture, and a convenient market are available. Truck gardening is carried on near centres of population that provide a ready market. Poultry-raising and bee-keeping offer opportunities in various districts throughout Canada. Fruit-growing is successful in British Columbia, and in Eastern Canada.

SELECTING A TYPE OF FARMING

In choosing a type of farming the prospective farmer should consider three factors: his likes and dislikes, his training and experience, and the possibility of finding a favourable location. Unless circumstances compel him to do so, there is no point in engaging in a type of farming in which he cannot find a measure of satisfaction and some enjoyment. If his training has fitted him specially for one type of farming, that type is likely to be most profitable for him.

A good dairy herd is essential for dairy farming. What breed is shown here? (Dept. of Agriculture photo)

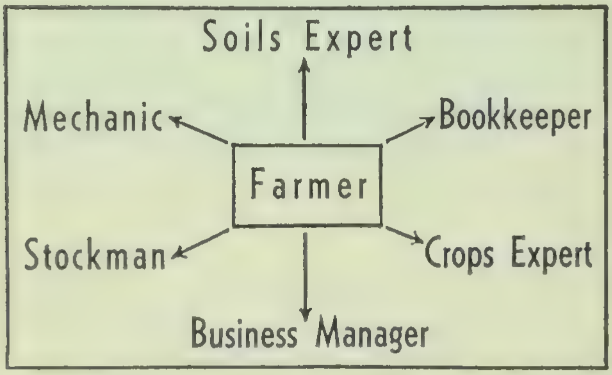
In determining the possibility of finding a favourable location, the farmer must bear in mind the conditions that are best suited to each type of farming—the kind of soil, the adequacy of the water supply, the amount of rainfall, the nature of the country, and the distance to a good market—as well as factors that will affect his social life and that of his family, such as the kind of roads in the locality, the distance to a good school and to a church. In districts where the rainfall is light, grain-growing is likely to prove most successful. The best grain farms are found on level or slightly rolling land with few trees. For growing grass for stock-raising, and for mixed farming, a good supply of water is essential. No matter what the product is, short hauls reduce profits less than long ones, but the perishable products of dairying and truck gardening can be sold profitably only if they are produced close to a good market.

Something to Do

Make a survey of your community to determine the types of farming carried on. Ask various farmers why they selected the types of farming in which they are engaged.

WHAT DOES A FARMER NEED TO KNOW?

To be successful, a farmer must be a good student and a keen business man. He must study carefully such problems as how to maintain the fertility of his soil; how to store moisture in his land for the use of his crops when they need it most; how to identify and control weeds, insect pests, and plant diseases; how to feed his live stock with the least waste; and how to plan and arrange his fields and buildings to save time and work. He must know the most profitable varieties of grain and breeds of live stock that can be produced in his locality; how much of each he should buy, and how and when to market them to obtain the highest prices. He must keep accurate accounts in order to determine which of his enterprises are yielding the greatest returns, and which, if any, are resulting in losses. He should also be a good mechanic, in order to be able to operate and repair his machinery with as little expense as possible.



A successful farmer must possess much knowledge and skill. Do you think it is easy to be a good farmer?

WHAT IS A CROP ROTATION?

In any type of agriculture that is to be sound and permanent, it is necessary to maintain the fertility of the soil. The continuous growing of one crop, such as wheat, reduces the fertility of the soil by removing large quantities of plant food elements and destroying fibre and humus. On the other hand, sweet clover crops return nitrogen to the soil, and grass crops restore fibre. Farmers have found from experience that it is a good practice to follow exhaustive crops, such as wheat, with restorative crops, such as clover and grass, in a

system of crop rotations. A *crop rotation* is the growing of a number of different crops in succession year after year, so that finally in each field the first crop is grown again, and the succession begins once more.

THERE ARE MANY ADVANTAGES IN ROTATING CROPS.

The chief benefits to be derived from good crop rotations are: (1) Different crops remove different plant foods from the soil; by rotating the crops it is possible to maintain a balance between the plant foods removed, thus prolonging the ability of the land to produce good crops. (2) Shallow-rooted crops, such as the grains, can be followed by deep-rooted crops, such as legumes, with the result that the feeding of the plants is distributed through a larger part of the soil. (3) By growing grass crops, weeds can be controlled. (4) Most insect pests and plant diseases attack only one kind or a very few kinds of crops. Therefore, the growing of a single crop encourages them, while a rotation of crops starves them and keeps them under control. (5) By adding fibre to the soil, grass crops reduce the danger of soil-drifting. (6) Because different crops require attention at different times, the work of the farm can be more evenly distributed throughout the year; for example, oats are sown later than wheat, and hay crops are cut before grain crops are ripe enough to harvest. (7) Providing for a variety of crops and products reduces the risk of farming and means that there is more likely to be some return from the year's work. (8) Usually the various products are sold at different times of the year, with the result that the farmer's income is more or less evenly distributed over the twelve-month period.

WHAT ARE THE ESSENTIALS OF A GOOD ROTATION?

In every good system of rotation three kinds of crops must be included: (1) cash crops: these are usually wheat; (2) restorative crops: grass to restore fibre, and sweet clover or

Crop rotation plots at the Dominion Experimental Farm, Ottawa. By conducting extensive experiments, the agriculturist discovers which crop rotations are best for different farm conditions. (Dept. of Agriculture photo)

alfalfa to return nitrogen; (3) cleaning crops, to destroy weeds: grass crops, summerfallow, or hoed crops.

COMMON ROTATIONS IN WESTERN CANADA

The crops to be grown in any system of rotation depend upon the locality. Even in one district, the same rotation will not be satisfactory on every farm. Each farmer must decide for himself the best rotation for his own requirements.

1. *Grain-growing Rotations.*—In some parts of the prairies, lack of moisture makes the growing of grass crops impossible. In these localities, grain-growing is the only profitable type of farming. In grain-growing, either a two-year or a three-year system of rotation may be practised.

(*a*) Two-year rotation: first year, wheat; second year, summerfallow. This simple rotation is followed in extremely dry areas. It conserves moisture, but exhausts the soil and removes fibre so that soil-drifting is encouraged.

(*b*) Three-year rotation: first year, wheat; second year, wheat; third year, summerfallow. In this rotation, oats or barley are sometimes substituted for part of the second wheat crop. Like the previous one, this rotation conserves moisture, but depletes the soil and encourages soil-drifting. Growing

two or more grain crops in succession also favours the growth of weeds.

2. *Mixed Farming Rotations.*—Where sufficient moisture is available, a greater variety of crops is possible, and more effective rotations can be arranged.

(*a*) Five-year rotation: first year, wheat; second year, wheat (or oats or barley); third year, hay; fourth year, pasture; fifth year, summerfallow. Sweet clover or grass seed or a mixture of both is sown with the second grain crop. The grain crop is harvested that year, and the grass or clover crop

1943

WHEAT	HAY	PASTURE
SUMMER FALLOW	OATS	WHEAT

1944

HAY	PASTURE	WHEAT
WHEAT	SUMMER FALLOW	OATS

A six-year crop rotation showing the location of the different crops for two successive years. Draw another plan to show the arrangement for 1945. How many years will elapse before each crop will occupy the same field as in 1943?

gets started. This rotation checks soil-drifting by adding fibre to the soil, returns nitrogen, helps to control weeds, and includes two cash crops of wheat.

(*b*) Six-year rotation: first year, wheat; second year, hay; third year, pasture; fourth year, wheat; fifth year, oats or barley; sixth year, summerfallow. This six-year rotation is much like the previous five-year one, but it has this added advantage: the grass crop, which requires a great deal of moisture, is sown with the wheat following summerfallow, when there is a good supply of moisture in the soil. In the fourth year of this rotation, the pasture is broken up about mid-summer, and the land is prepared for the wheat crop of the following year.

Something to Do

1. Write to the Agricultural Extension Department, University of Saskatchewan, Saskatoon, for a copy of a booklet entitled *Guide to Farm Practice in Saskatchewan* for use in your school. This booklet contains much valuable information about a wide variety of farm problems. (One copy only should be requested for each school, and the teacher should sign the letter.)
2. Find out what crop rotations are being practised in your locality.

Review Questions and Exercises

1. Give three reasons why agriculture is regarded as the most important industry in this country.
2. Make a list of problems of farm management.
3. What types of farming are practised in Western Canada?
4. What determines the type of farming that is profitable in a particular district?
5. What is a rotation of crops? Outline the advantages of this plan of growing crops.
6. What are the essentials of a good crop rotation?
7. Suppose that a five-year rotation is being practised on a farm. (*a*) How many fields are required? (*b*) How must the fields compare in size? (*c*) How many crops are grown each year on the farm?
8. Is the following rotation a good one: wheat, wheat, oats seeded to grass, hay, pasture, summerfallow? Why?

WHY SHOULD A FARMER KEEP ACCOUNTS?

Suppose that you were managing a business in which there were several departments. Suppose, too, that you kept no accounts but put all the money received from sales into one cash box. At the end of the year, you would probably know whether your business as a whole had been profitable or otherwise, but could you determine whether all departments had made a profit or not? If one department had been operated at a loss, thus reducing your total profit, would your business methods show this, so that changes could be effected and the

Whether tractors are more economical than horses depends upon several factors, such as the size of the farm, etc. This farmer has apparently decided that, as a source of power, horses are cheaper than tractors. Do you think he is right? Why? (Dept. of Agriculture photo)

department made profitable? Every efficient business manager, in order to keep a check on all departments, must have a system of accounts.

A farm is a business, often having several departments or branches. Every farmer should keep accounts that will indicate which of his enterprises are profitable and which are not. This information will probably enable him to remedy the cause of losses and increase his total annual profit.

In this system of accounts, the farmer should include a yearly inventory. An *inventory* is a record of (1) everything that the farmer owns—all his property of every description, together with notes or accounts that others owe him—and (2) his liabilities and debts. In the inventory, values are fixed at the prices the various pieces of property would bring if offered for sale. The value of buildings is calculated by deducting an amount, usually five per cent, from the previous year's value to allow for depreciation. Depreciation on machinery is usually more than five per cent. The form in which the inventory should be recorded is shown on the next page.

A SIMPLE INVENTORY

Assets	
Land and improvements (house, barn, fences, etc.)	$11,500.00
Live stock (horses, cattle, etc.)	1,150.00
Machinery	1,255.00
Farm produce (wheat, oats, hay, etc.)	830.00
Notes on accounts owing to the farmer	150.00
Cash on hand	25.00
Cash in bank	200.00
Total Assets	$15,110.00
Liabilities	
Mortgage on farm	$6,000.00
Notes owing	750.00
Accounts or bills not paid	145.00
Total Liabilities	$6,895.00
Net Worth or Balance of Assets over Liabilities	$8,215.00

A comparison of the farmer's net worth with his net worth at the end of the preceding year indicates the loss or profit on the total year's business; but the inventory does not show on which of his enterprises profits or losses have been made. For this reason, the farmer should keep records of the receipts and expenditures of each branch.

All accounts should be neatly recorded and strictly accurate. Some farmers carry in their pockets small books in which they note transactions as they are made. At the end of the day the transactions are properly entered in account books. Farm accounts should be as simple as possible. For the majority of farmers, well-kept day books will record satisfactorily the essential details of their farm business.

From his account books, the farmer can calculate the cost of producing his crop and live stock. Production costs vary greatly. They depend largely upon local conditions and the farming methods employed.

Something to Do

1. Find the cost of producing an acre of wheat in your locality. Ask experienced farmers the cost of the various items listed in the account outline below. Each member of the class should secure as accurate information as possible from various farmers. Estimates collected should then be averaged, and a final estimate made. Copy the account outline into your science note-book, and arrange the various items and amounts in the proper places.

1942	WHEAT (100 ACRES)	EXPENSES	RECEIPTS
April	Ploughing		
	Harrowing		
	Seed		
	Cleaning and pickling of seed . .		
	Seeding		
	Harrowing after seeding		
June	Insurance		
August	Harvesting		
September	Threshing		
November	Rent, taxes, interest on money invested in land		
	Selling charges — commission, freight, etc.		
	Sold 2000 bushels		
	Profit (or Loss)		

NOTE.—The cost of summerfallowing should be charged to the succeeding crops, the greatest charge being made against the first crop.

2. List the expenses and find the cost of producing a $\frac{1}{4}$-acre plot of potatoes. Use the method outlined in Exercise 1.

MARKETING FARM PRODUCTS

Suppose again that you were in business and that you had a stock of goods of the highest quality. You can readily see that, if you were to offer your goods for sale at a time of

The tiller combine, a machine that ploughs and harrows the soil and sows the seed in one operation. The farm manager must consider carefully a number of factors before he purchases a new machine. Such a purchase may decrease his operating costs, or he may discover later that he has a machine that he does not require or that is too expensive for him to operate profitably. (John Deere Plow Co. photo)

year when people did not want them, you would not be able to sell them, or if you did succeed in selling them, they would bring a very low price. You can see, too, that if you allowed your expenses to become too great, there would be no profit left, even if the goods were sold for a fair price.

In farming, unwise marketing may quickly change possible profits into losses. Profits are largely determined by two factors: (1) the cost of marketing and (2) the price obtained for the product. Marketing expenses include a number of items which may be very costly. In the case of wheat, for example, they include the cost of hauling the grain to the shipping centre, the charge made at the elevator for loading the grain, freight charges, and the commission paid to the agent who sells the grain. In marketing live stock, freight, commission, and other charges must be paid. The farmer must watch these costs very carefully and keep them as low as possible. The price obtained for a product, as we have seen, depends very largely upon the demand for the product. Consequently, the farmer must know the time of the year when the demand for each of his products will be the greatest

and the price therefore the highest. If products are sold at the wrong time, unprofitable prices may have to be accepted.

In pioneer days, each farmer tried to solve his problems by himself. Later, farmers began to co-operate or work together. Organizations, known as *pools,* were formed for the purpose of marketing the products of the farm more profitably. At present there are a number of pools—the Dairy Pool, the Live Stock Pool, the Poultry and Egg Pool, and the Wheat Pool.

By organizing as a group the farmers of Western Canada built many "pool" elevators, like the one pictured here.

Some of the advantages that may result from co-operative marketing are: (1) A central assembling point may be established, and by gathering together large shipments the expense of shipping may be reduced. (2) Products may be sold direct to the consumer, thus saving the commission charges of an agent or middleman. (3) A paid manager who understands the business of marketing may be employed. (4) Facilities may be provided for storing products for a time in order to prevent flooding the market. (5) Farmers may be induced to keep the quality of their products up to a high standard, and so be able to obtain higher prices for their goods. When this happens, it benefits the consumer also, because he receives full value for every cent he spends.

When a co-operative association or a pool is organized, the members elect a president, a secretary-treasurer, and a small board of directors. Expenses are shared by the members on the basis of the products marketed by each. Receipts are also apportioned according to the quantity and the quality of the products marketed by each member, every member receiving the same return for the same quantity and grade of products delivered in the same pool period.

An attractive farm home. Do you think the owner intends to live here permanently? Why? (Dept. of Agriculture photo)

Something to Do

1. If there is a local or a branch of one of the provincial pools in your community, ask a member to tell you about it. Ask him (*a*) why the pool was formed, (*b*) how it is organized and managed, and (*c*) what are the marketing advantages it offers to its members.

2. Visit your nearest centre where eggs or poultry are being graded and packed for shipment. Find out the requirements for the top grade. Ask someone to tell you what is meant by the *standardization of farm products* and what advantage the farmer derives from it. Of what advantage is standardization to the people who purchase and use farm products?

THE FARM AS A HOME

What makes a home? Picture to yourself a home surrounded by a hardy windbreak to afford shade and protection from wind and storm, a home framed with shrubs, cool green lawns, and colourful flowers, a home where the buildings are attractively painted to improve their appearance and prolong their life. Such a home becomes deeply rooted in one's affections and endures among one's fondest memories. With the expenditure of a little time and thought and energy, such a home can be made on every farm. Careful planning during the long winter evenings, and a will to put the plan into effect during the summer months, can clothe the most humble building in a mantle of green and showy colours and transform it into a home that will be a constant source of pride.

But to make such a home requires an incentive—an interest in farm activities and a feeling of security and permanence. A system of mixed farming, by lending variety, usually adds to the interest of farm life and at the same time increases the feeling of security by removing, to a great extent, the risk and dread of total failure. Careful study of the problems of the farm, a search for information about how to solve them, the development of a system of crop rotations to maintain the fertility of the soil are all factors that make for permanence in agriculture. If the purpose of farming is merely to make money, then the farm becomes merely a business and is never likely to become a home. But if the farmer is content with the possibly slower but usually surer returns of mixed farming, if he adopts sound methods in all his operations, and if he finds a place in his season's activities to plan and plant his grounds, then the farm may become for him a home as well as a profitable enterprise.

A school potato club fair. These pupils conducted a practical experiment in an attempt to raise bigger and better potatoes.

HOW A GOOD COMMUNITY SPIRIT HELPS

Progress is likely to be made in a community only if a good community spirit prevails. To build up a good community spirit, every resident must take an interest in his community and do all he can to make it a place of which he can justly be proud. He can probably make his greatest contribution by joining a worth-while organization, such as an Agricultural

Judging poultry for egg production at a farm boys' camp. Each boy is trying to pick the best bird for first place and others for second, third, and fourth places. He will then mark his placings on his score card and write his reasons to justify them. The cards are marked later by experts, and the best judges receive awards.

Society or other farmers' organization, a Home Makers' Club or Women's Institute, a Red Cross Local, a debating or literary society, or a Boy Scout or Girl Guide Patrol. Such groups help in many ways to improve rural community life.

WHAT COMMUNITY ORGANIZATIONS MAY DO

Some of the ways in which organizations may contribute to the life of the community are: (1) By bringing the people together to become better acquainted, and to discuss common problems and help one another to solve them. Such organizations may do much to link up country and village, town and city. (2) By studying means of improving homes and schools and community conditions. (3) By arranging for demonstrations, discussions, and addresses dealing with farming operations, such as gardening, weed control, and feeding live stock. Activities of the home, such as the care and feeding of children, the canning of fruit, and home handicrafts, provide interesting topics for discussion at community meetings. (4) By raising money to build a community hall to be the centre of the general activities of the district. (5) By establishing beautiful parks and playgrounds. (6) By improving

the appearance of road allowances and other community property by organizing campaigns to control weeds, sow grass seed, etc. (7) By holding debates on topics of community and general interest. (8) By affording opportunities for members to practise public speaking and to learn the chief rules of procedure in public meetings.

Something to Do

1. Find out what organizations are active in your community. Arrange for a member to come to your school and tell you about the history and the work of one of them.

2. If you are not a member of an organization that is working in the interest of your community, consider what organization you could join. Is a Boy Scout or Girl Guide Patrol active in your locality? Have you a Junior Red Cross Society, a bird club, or a nature science club in your school? Perhaps you could organize a live stock judging club, and arrange for a cup or a shield to be donated for annual competition.

3. Investigate and discuss the possibilities of improving rural life in your province.

4. Debate the following resolution: Resolved that rural life in Western Canada provides a boy or girl with a better opportunity for all-round development than does city life.

Review Questions and Exercises

1. Why should a farmer keep accounts?

2. What is an inventory? What information does it give a farmer about his business?

3. What other items, in addition to the cost of cultivation, seed, seeding, harvesting, and threshing, should a farmer take into account in calculating the cost of producing an acre of wheat?

4. What are some of the disadvantages to farmers of marketing their products individually?

5. Briefly outline the advantages of co-operative marketing of farm products.

6. The development of a system of permanent agriculture and the establishment of enduring farm homes go hand in hand. What does this statement mean?

7. Briefly state six ways in which rural organizations may be active in the interests of a community.

8. It has been stated that a boy or girl who grows up on a farm experiences many pleasures not commonly enjoyed by city dwellers. List the things about farm life that appeal to you.

Test your Knowledge

Write the numbers from 1 to 10 in three columns in your science note-book, and after each number write the word *true* or the word *false* as you find each of the following sentences to make a true or a false statement.

1. Many other industries and businesses depend upon agriculture for their prosperity.
2. It requires brains, skill, and knowledge to farm successfully.
3. In all parts of Western Canada, mixed farming is more desirable than grain-growing.
4. The fertility of the soil cannot be maintained unless a good system of crop rotations is practised.
5. A succession of crops, such as wheat, oats or barley, and summerfallow, is a good mixed-farming rotation.
6. A yearly inventory will show a farmer which of his enterprises have been profitable and which have not.
7. It is important to market farm products at the right time of year.
8. Marketing is the least important of the farmer's problems.
9. Conditions such as soil, distance to market, etc., being the same, a farm on which trees and shrubs have been planted and buildings painted, is more valuable than one on which these have not been done.
10. A good citizen is interested and active in the improvement of his community.

I have seen the largest seeds
Degenerate, unless the industrious hand
Did yearly cull the largest.

—VIRGIL.

CHAPTER SEVEN

CHAPTER 7

HOW SEEDS GROW INTO PLANTS

What is a seed? How are seeds formed? How does a seed become a plant? How are seeds adapted for their work? When pea seeds germinate, they absorb enough water to double their weight. How does the water get into the seeds? Can good crops be grown by sowing poor seed? How can you recognize good seed?

On a warm, spring-like day during the Easter vacation, Mary Jones and her cousin Edith, from the city, went on a nature hike across the field to a valley not far from the Jones's farm. As they tramped along, they observed on every hand many signs of spring. Mary's father was seeding wheat on the summerfallow. The hillsides were tinted with the rich green of the young grass. Every now and then a gopher sat up, looked the girls over carefully, then scampered into his hole, only to poke his head out again for another look. Crows flew overhead, breaking the stillness of the spring morning with their familiar cawing. Young colts with gangling legs frisked about their mothers in the pasture.

Suddenly Mary exclaimed: "Oh, see what I've found—a bird's nest, with five baby horned larks in it! And I almost stepped on it."

"I just love spring," said Edith with enthusiasm. "It's such fun to see the baby animals and birds, and the crocuses that bloom so early."

In the field and on the hillside the girls found hundreds of tiny plants pushing their first leaves through the moist soil.

"Where do all these little plants come from?" asked Edith.

"Why, from seeds, of course," answered Mary.

"I wonder what kinds of plants they'll grow to be. Do you think they'll have flowers, Mary?"

Mary stooped down to look more closely. "Here is a plant that has leaves like grass," she said, "and grass doesn't have flowers, does it?"

"I don't know; let's ask your father when we get home," was the reply.

When the girls put their question, Mr. Jones explained to them that plants which grow from seeds must of necessity have flowers, which, in turn, produce more seeds. "And to this rule," he said, "grass plants are no exception. But the flowers of grass plants, including wheat and oats, are not brightly coloured, and so the casual observer may easily overlook them. Isn't it wonderful that from a seed that is put into the soil there will grow a living plant like the one from which the seed came? Imagine what confusion there would be if this was not true!"

Mr. Jones was called away before Mary and Edith had nearly finished plying him with questions about seeds. They wanted to ask him, for example: Is the seed alive before it starts to grow? What causes a seed to grow? Why does it produce a plant like the one it came from? How can a farmer or a gardener be sure his seed will grow?

The girls decided to experiment to find the answers. You can find them by the same method.

Something to Do

Problem.—How is a bean seed adapted to perform its function?

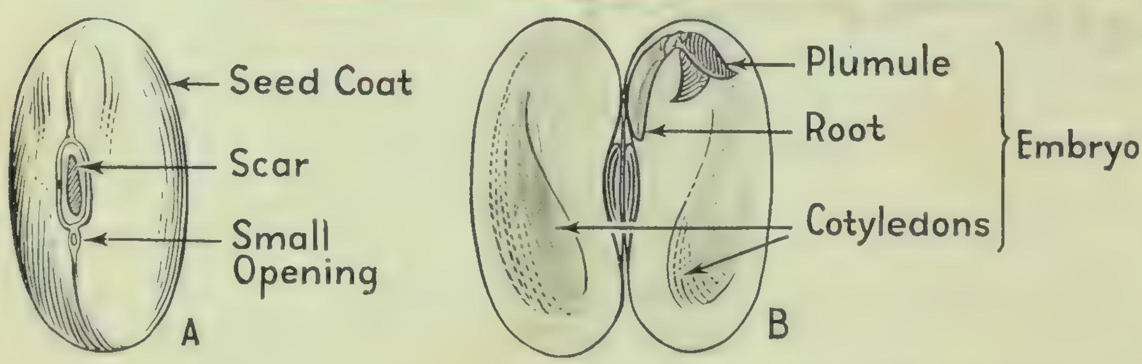
Materials.—Enough dry beans and beans that have been in water overnight to provide one of each for each member of the class; a magnifying glass.

(*a*) Compare a dry bean with one that has been soaked, and note any difference in external appearance, size, and weight.

The skin-like outer covering is a *seed-coat.* It is waterproof, and so helps to keep the seed from drying out completely. Find the *scar,* which shows where the bean was attached to the pod. Close to the scar locate a small opening in the waterproof skin. When the seed is in water or planted in moist soil, this opening admits moisture, which is needed for germination.

Make a labelled drawing to show the external structure of a bean seed.

(*b*) Split open a bean that has been soaked, and examine its internal structure. Notice how it divides into two nearly equal parts. These halves are the seed-leaves, or *cotyledons*



An external view of a common bean (A); and a bean seed split open (B). Do you find the same parts in your specimen?

(kŏt-ĭ-lē′dons); they serve the young seedling temporarily as both food and leaves. Observe the small, plant-like structure lying between the cotyledons. Note the *plumule* (plōō′mūl). This is the first bud of a plant growing from a seed. It develops into stem and leaves. How many leaves do you find, and how are they veined? The end opposite the plumule is the *root.* The plumule and the root, together with the cotyledons, form the *embryo* (ĕm′bri-ō). Examine the embryo under a magnifying glass.

Make labelled drawings to show the internal structure of a bean seed.

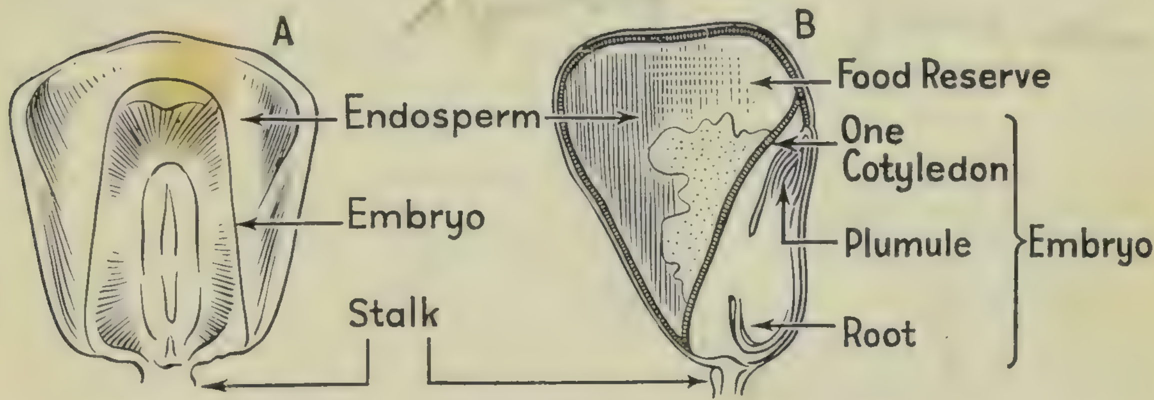
Common examples of seeds that closely resemble the bean in structure are peas, squash, and sunflower. If possible, you should examine some of them to find in what ways they are all alike.

Something to Do

Problem.—What parts has a corn grain which fit it to perform its functions?

Materials.—Two grains of corn that have been soaked overnight in water; a sharp knife or safety razor blade; a magnifying glass.

(*a*) Carefully examine the external features of the corn kernels. Notice the depression in one side of the kernel. Under this lies the *cotyledon*. There is only one cotyledon in corn. Surrounding the cotyledon is the *endosperm* (ĕn′dō-sperm), which contains the food reserve. In golden corn, the endosperm is



An external view of a corn kernel (A); a lengthwise section through the corn embryo (B). What is the food reserve for?

yellow, and the cotyledon is white. The seed is protected by a hard outer covering, or bran. Find, at the small end, the *stalk*, by which the kernel was attached to the cob.

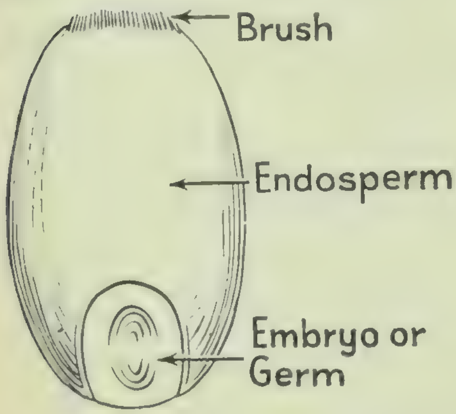
Make a labelled diagram to show the external appearance of a grain of corn.

(*b*) Separate the cotyledon from the endosperm. Embedded in the cotyledon find a slender, pointed structure. The end pointing towards the broad end of the kernel is the *plumule*; the other end is the *root*. The plumule and the root, together with the single cotyledon, form the *embryo* plant of the corn. Examine it under the magnifying glass.

Cut a lengthwise section through the middle of the embryo in your second kernel of corn. Find the parts as before, namely, endosperm, cotyledon, plumule, root, stalk, and outer covering.

Make a labelled drawing to show a lengthwise section through the embryo of a kernel of corn.

Examples of plants that produce seeds having the same parts as corn are: wheat, oats, barley, and the various kinds of grasses. These plants resemble one another not only in their seeds, but also in their roots, stems, and leaves. They all belong to the grass family.



A wheat kernel. Which does it resemble more closely, a bean seed or a corn kernel? Why? Give a reason for your answer.

Something to Do

Examine a number of other seeds to find out which are like the bean and which resemble the corn in structure. Be sure to soak some of each kind of seed for a while before you study them.

IS FOOD STORED IN SEEDS?

Something to Do

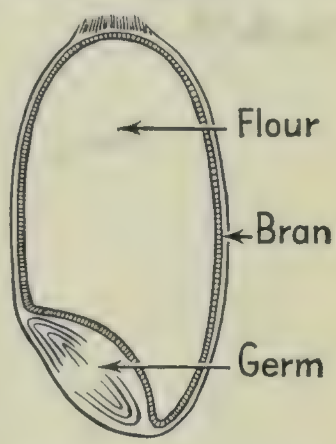
Problem.—Is starch stored in seeds, and if so, in what parts?

Split open beans, peas, corn, squash, and other seeds that have been soaked in water. On the exposed inside of each seed drop some weak iodine solution, and allow the seeds to stand for a few minutes. Which parts of the seeds turn blue or purplish black? What does this indicate? Is starch stored in the embryo of a bean or pea seed? Observe that in corn and wheat, starch is stored chiefly outside the embryo—in the endosperm. For what purpose do plants store food in seeds?

The newly germinated plant cannot make plant food; until it is fully established and able to make its own food, it must depend for its supply on the food stored in the seed. The greater the supply of this stored food, the more vigorous the seedling should be and the more rapid its growth. As a result, it will be less likely to be blown out by winds, crowded

out by weeds, damaged by plant diseases, or destroyed by insect pests.

The seed's habit of storing food reserves is of great importance not only to the plant but also to man. Many seeds contain sugar, protein, and oil, as well as starch. All of these we use in some form. From wheat we get flour for bread, cakes, pastry, macaroni, and other dishes, and a wide variety of prepared breakfast foods. Oats supply our oatmeal; and corn, our corn flour, cornmeal, corn syrup, and cornstarch. Castor oil is obtained from castor beans; and linseed oil, so widely used in paints, is oil from the seeds of flax.



What use do we make of the food stored in the endosperm? Of what value is the bran?

Review Questions and Exercises

1. Describe the structure of a common bean seed. What is the function of each part of the seed?

2. Describe both the external and the internal structure of a kernel of corn. Use drawings to assist you. How is the kernel fitted to grow into a corn plant?

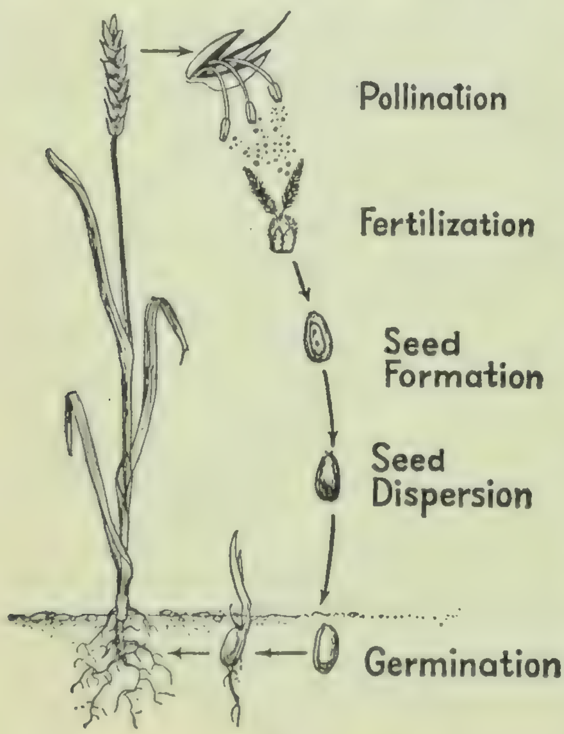
3. Why do plants store food in seeds? In what forms is the food stored? State at least three uses that we make of this food reserve.

4. Is a seed alive before it is planted? Give proof in support of your answer. How has your study helped you to appreciate the wonder of a seed?

GERMINATION OF A SEED

It is well known that the seeds of some plants will grow, if planted, even after they have been kept in a dry place for years. Doesn't it seem wonderful to you that a tiny plant can remain asleep for ten, fifty, or a hundred years, and then, like the Sleeping Beauty, suddenly be awakened by the touch of the warm, moist soil? This awakening from the dormant or

resting condition, in which the embryo plant shows practically no signs of life, to a state of active growth is called *germination* (jer-mĭn-ā'shŭn). Seeds are said to be germinated when the root and plumule have broken through and project beyond the seed covering, but germination is not complete until the little plant is able to live independently of the stored food in the seed. It is very important for the farmer and the gardener, and interesting for all of us, to know what are the most favourable conditions for germination.



The life cycle of a flowering plant. Follow the arrows, and explain the importance of each process in the life of the plant.

Something to Do

Problem.—What conditions are necessary for germination?

1. Place ten beans (or other seeds) in dry sawdust or soil in a warm room. Put an equal number of the same kind of seeds under the same conditions, but keep the soil moist. After a few days, observe which seeds have germinated.

2. Plant beans (or other seeds) in soil in two flower-pots or cans. Water both. Keep one container in a warm place and the other in a decidedly cool place. Examine them in a few days. Which seeds have sprouted? What does this show?

3. Plant beans (or other seeds) in soil in two separate pots. Keep the soil in one pot moist but not over-wet, and the soil in the other pot fully saturated or flooded at all times, to exclude the air. Place both pots in a warm place. Do the seeds in both pots germinate? If not, why not?

What conditions do you conclude are essential for the germination of seeds? Is it possible to supply seeds with an excess of any of the things they require?

Your experiments have shown that, to bring about quick and healthy germination of seeds, the soil must have warmth, air, and moisture. Hard soils or soils that have become packed, as clay soils so readily do, do not admit air and warmth freely and have little capacity for holding moisture. You may have noticed how easily a trodden road sheds rain, while a newly ploughed field or garden absorbs all that falls on it. The soil, then, should be broken up by cultivation or made friable, so that it will admit the necessary air and warmth and be able to hold a large amount of water. Clay soils may be made more friable, and less likely to become hard, by the addition of rotted manure, sand, or sifted soft-coal ashes.

HOW CAN A FARMER TELL WHETHER HIS SEED WILL GROW?

You cannot determine by looking at seed whether or not it will germinate even if conditions are favourable. Farmers have sometimes seeded large acreages, only to discover later that the germs in the seeds were dead. What a costly mistake to make! Sowing poor seed may result in very serious losses in both crop and labour. No farmer, therefore, can afford to sow seeds of doubtful germination strength. Nor is it sufficient for the farmer to know merely that the seeds are alive and will germinate; he should know also that they will sprout quickly and produce vigorous seedlings which will soon become firmly established in the soil. Why?

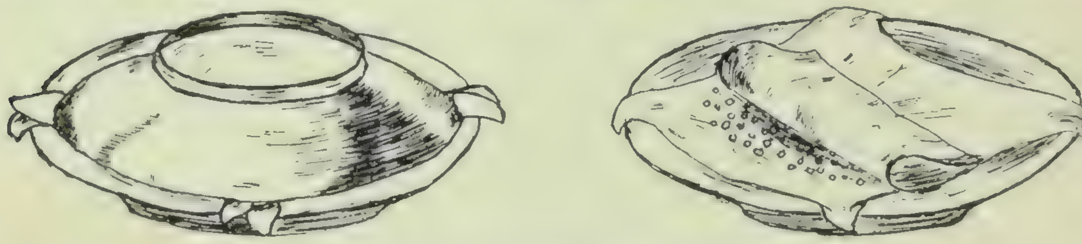
To determine whether seed is suitable for sowing, it should be tested for germination. To be of any value, the tests must be made with *average* samples from the bin of wheat or other grain that is to be used for seed. An average sample is obtained by taking equal quantities of seed from various places and from different depths in the bin and mixing the seed thoroughly. The germinating strength of this uniform sample is then determined by performing a number of experiments and taking the average of the results obtained. The following is a simple method of conducting such tests.

Something to Do

Problem.—Is there any difference in germinating strength between plump, high-quality wheat and thin, low-quality wheat?

Apparatus and Material.—Four dinner plates, blotting paper, samples of good, plump wheat and of shrunken wheat.

Method.—Put two or three layers of blotting paper in the bottom of each of two dinner plates. Thoroughly wet the paper. Spread a hundred kernels of the plump wheat over the blotting



A simple but useful germinator.

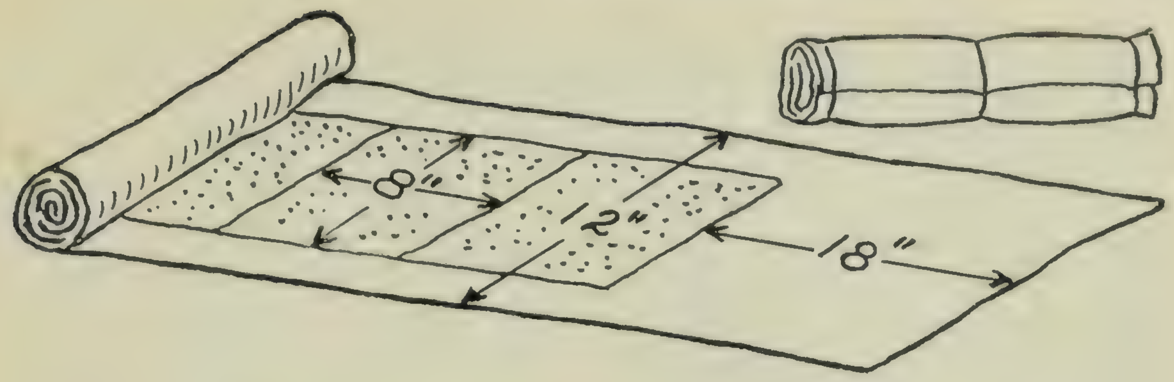
paper in one plate. Arrange a hundred kernels of the shrunken wheat similarly on the second plate. Invert a dinner plate over each of the plates containing the wheat. Keep them in a warm place. Pour in enough water from time to time to keep the blotting paper wet, without having the seeds standing in water.

Make observations each day for a week. Each day move to the side of the plate those seeds that have germinated both root and plumule. Good wheat should germinate ninety-five per cent in three days. Keep a record like that suggested below under *Observation.*

NOTE.—As an alternative, a *rag-doll germinator* may be used. For instructions see the illustration on the opposite page.

Observation.—

LENGTH OF TIME IN DAYS	PERCENTAGE OF SEEDS GERMINATED	
	HIGH-QUALITY WHEAT	LOW-QUALITY WHEAT
1		
2		
3		
4		



THE RAG-DOLL SEED GERMINATOR AND TESTER

To make a rag-doll germinator: Cut a strip of fairly heavy flannel or cotton ten or twelve inches wide and two yards long. With a soft lead pencil, mark off squares as indicated in the diagram. Dampen the cloth. Place fifty large or a hundred small seeds in each square. Seeds must not touch one another. Roll up the cloth, and loosely tie each end and the middle of the roll with elastics or strings. Soak the roll in a pail of luke-warm water for several hours. Drain off the water, and cover the pail with a damp cloth and newspapers. Keep the roll damp, but not wet, and in a warm place. After five or six days the roll may be opened and a count made to determine the percentage of seeds that have germinated.

Which quality of wheat germinated the higher percentage? Which germinated the higher percentage in three days? Which had the greater number of vigorous shoots?

Conclusion.—What does the experiment show regarding the germinating strength of high-quality and of low-quality wheat? How do you account for these results? Which sample would produce the more vigorous seedlings?

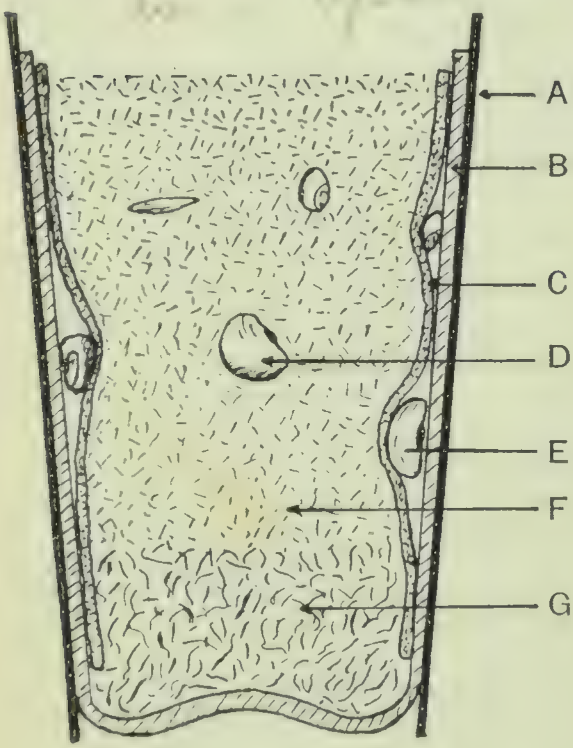
Application of Experiment.—1. Test your father's seed wheat or garden seeds to determine their germinating strength and fitness for use. Be sure to mix your seed well to get a fair sample.

2. Give as many reasons as you can why only good, plump seed of high germinating quality should be sown. Why are strong seedlings as important as a high percentage of germination?

HOW A SEED GROWS INTO A PLANT

Under favourable growing conditions, the germ, or embryo, of a seed sends roots down into the soil and leaves up out of the soil, thus establishing the plant on a self-supporting

basis. To see this transformation taking place, set up the following experiment, and watch the development of the embryo from day to day, as it is awakened to active growth.



An experiment in germination: A, a paper cover to exclude the light; B, a glass tumbler; C, blotting paper; D, seeds planted in the sawdust; E, seeds planted with embryos next to the glass; F, sawdust or fibre material; G, coarse material in the bottom of the tumbler to provide drainage.

NOTE. — This experiment should be set up as soon as the study of seeds is begun. Each pupil should perform the experiment for himself, either at school or at home.

Something to Do

Problem.—Do the embryo plants in different kinds of seeds waken up and grow in a similar manner?

Apparatus and Material.—A glass tumbler; brown wrapping paper; blotting paper; sawdust; bulb-fibre-compost, dried moss, or excelsior—enough to fill the tumbler when tightly packed; three seeds each of the bean, pea, corn, and wheat; pins.

Method.—Soak the seeds overnight in water. Completely cover the outside of the tumbler with two or three layers of the brown wrapping paper. Use pins or mucilage to fasten the free ends of the paper covering. The cover should fit snugly to shut off the light, but should slip off the tumbler easily when desired. Fit a cylinder of blotting paper around the inside of the tumbler. Remove the outer covering temporarily. Then fill the bottom of the tumbler with excelsior, coarse bulb-fibre, or similar material to provide proper drainage. Above this, pack sawdust or fine fibre to within half an inch of the top of the tumbler.

Plant one seed of each kind at a depth of from one to one and a half inches (depending upon the size of the seed) beneath the surface of the sawdust. Next, place two seeds of each kind at varying depths (from one to three inches) between the blotting paper and the glass tumbler, with the embryo side of each seed lying next to the glass. Replace the outside cover.

Soak the sawdust with water. Keep it in a warm place. Add sufficient water from day to day to keep the sawdust and blotting paper moist, without having water collect in the bottom of the tumbler.

The cover paper should be removed each day and the progress of germination of each seed carefully noted. A set of drawings should be made to show the method of germination of each kind of seed. Begin your drawings on the second day after you set up the experiment, and make additional drawings every two days for two weeks or until the seedlings are well developed.

Observation.—Watch to see which part of the embryo emerges from the seed-coat first, the root or the plumule. Look for the development of secondary roots and root hairs. Observe how the two cotyledons of the bean are lifted up. Does the same thing happen with the cotyledons of the pea? Does the single cotyledon of corn or wheat appear above the surface? Watch the seedlings as they come up through the sawdust. Which seeds *push* and which *pull* their leaves above the surface?

Conclusion.—In what different ways do the dormant plants in different seeds awaken and grow?

Application.—Observe seedlings that are growing in your garden, or seedlings that you are starting in flower-pots in the house. Which pull their leaves above the ground like the bean? Which germinate like the corn?

GERMINATION OF A BEAN SEED

If a common bean is planted in soil under favourable conditions, it at once begins to absorb moisture, thus causing the cotyledons to swell and to burst the seed-coat. The little plant-like structure, which hitherto has lain inactive in the dry seed, now becomes active and begins to require food. This

it secures, for the time being, from the supply stored for the purpose in the cotyledons. The root grows out from between the cotyledons and becomes firmly established in the soil. Thus rooted, the plant pushes up towards the sunlight and the air, assuming a peculiar crook-neck shape as it lengthens. With its inverted free end it pulls the cotyledons after it. Once it has brought these to the surface, it straightens up

Stages in the germination of the common bean: A, the seed-coat still retained; B, the binding of the shoot; C, the cotyledon; D, a leaf from the plumule; E, the primary root; F, a secondary root.

and lifts them to the light. The cotyledons now spread out and expose the true leaves. Established thus with leaves, stem, and roots, the plant is now able to produce food for itself. The process of germination is complete.

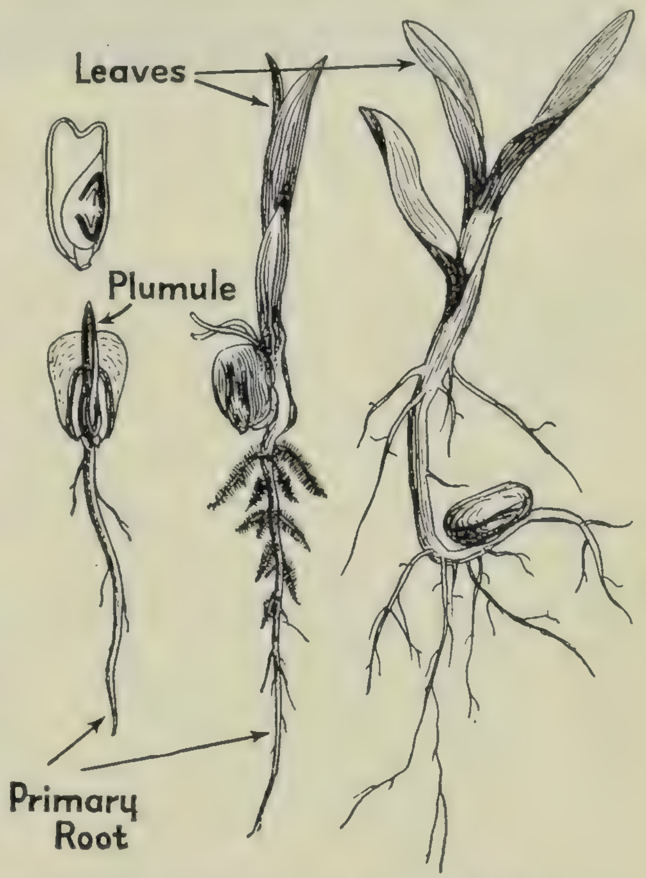
GERMINATION OF CORN

In the development of its seedling, corn differs from the common bean in several ways. The cotyledon of corn remains in the soil. It assists growth by digesting the starch of the endosperm, thus changing it to sugar—a form in which it can be used by the developing plant. The plumule of corn has a sheath-like covering over the leaves, which are wrapped

closely together to form a slender cone that pushes straight up through the soil with little effort.

Review Questions and Exercises

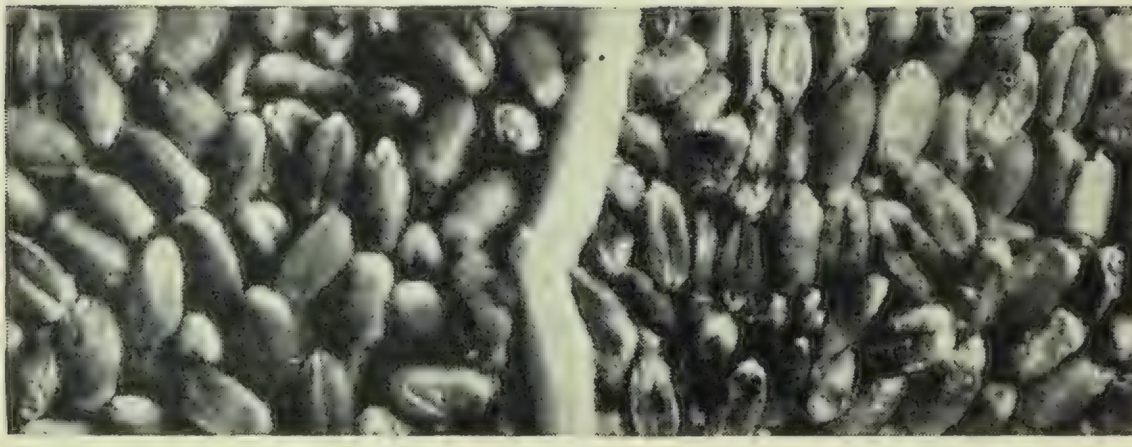
1. Define or explain the meaning of germination. When is germination complete? Draw a young bean or corn seedling.
2. State three conditions that are necessary for germination.
3. Describe the development of (*a*) a bean seedling, (*b*) a corn seedling.
4. Why are germination tests important? Describe an experiment by which you could determine the fitness of a sample of grain for seeding purposes.
5. Compare bean and corn seeds in regard to (*a*) structure, (*b*) method of germination.
6. How are seeds adapted for the work they do? In answering this question, bear in mind the seeds that have been studied in this chapter.
7. The best temperature for the germination of wheat and oats is from 77° to 88° F.; for pumpkins, from 93° to 111° F.; for corn, from 99° to 111° F. Which of these plants are suited to early seeding, and which to late? On what dates are they usually planted?



The germination of corn. How is the plumule protected as it pushes up through the soil?

GOOD SEED PAYS.

Many factors that affect the growing of crops are beyond the farmer's control. He cannot, for example, regulate the amount of sunshine or rainfall, or prevent the occurrence of



Good seed (left) and poor seed (right). Why is one sample good and the other poor?

hailstorms. But one factor he can and should determine—the quality of the seed he sows. It is usually possible to obtain good seed with very little extra effort or cost.

The wise farmer or gardener sows only the choicest seed he can secure, because he knows that usually the best seed produces the largest and most profitable crops.

Seed of a high quality gives the crop a good start. As a result, the crop is well established before weeds can grow; it is better able to withstand unfavourable conditions that may occur during the growing season; and it ripens before the fall frosts can harm it. In these and in other ways grain grown from good seed has a very much better chance to do well than that produced from poor seed.

The farmer who sows poor seed is a gambler. He takes unnecessary risks and endangers his crop. Poor seed may produce satisfactory results if the soil is good and moisture happens to be abundant just at the right time; but if drouth occurs, or disease attacks the crop, only sturdy plants will survive. Only exceptionally favourable conditions can produce strong plants from poor seed. Poor seed may starve the crop before it has a chance even to get started, and so reduce very greatly both the yield and the quality. Good seed is the only safe seed. Good soil deserves good seed.

WHAT ARE THE CHARACTERISTICS OF GOOD SEED?

When buying seed, it is important not only to select good seed but also to select seed of the right variety. If you wish, for instance, to grow sweet peas with large, showy flowers, it is useless to purchase seeds, no matter how good, of a variety that has not been carefully developed to produce such flowers. In districts that are suited only to early-ripening wheats, it would be useless for farmers to sow seed, even of the best quality, of varieties that have not been proved to have the ability to ripen early.

The following characteristics of good and poor seeds apply to all kinds of grain and other seeds.

Good Seed is:	Poor Seed may be:
Large, plump, heavy.	Small, shrivelled, and light.
Bright in colour.	Dull coloured, or bleached.
Free from smut, must, or damage by frost.	Smutty, musty, injured by frost.
Clean, that is, free from weed seeds, chaff, etc.	Dirty, full of weed seeds, straw, etc.
Pure, not mixed with other varieties or other kinds of seed.	Impure, mixed with other varieties or other kinds of seed.
Well ripened.	Green and shrunken.
Of good germinating power, containing a large percentage of live, strong seeds.	Of low vitality; many dead seeds present.

It is not always safe to judge seed by its appearance. Plump, apparently well-formed seed often contains many dead seeds and is unfit in other ways to sow. As you have already learned, it always pays to make sure of the quality of seed by testing it for germination before sowing it. Many farmers and gardeners test their grain and seeds each spring. Testing should be done early, so that new seed may be obtained if the tested samples prove to be unsatisfactory. If a farmer does not wish to purchase new seed, he may sow more thickly to allow for the seeds that will not grow.

Something to Do

1. Bring from home samples of seed wheat, oats, or barley for the purpose of testing them for germination. Be sure to mix the grain in the bins thoroughly before you take the samples for testing. Why is this important? You may test either by following the method described on page 172 or by using a rag-doll germinator. Remember that, unless a seed sprouts strongly (both root and stem), it cannot be regarded as having germinated satisfactorily. Work carefully so that your results will be accurate.

2. Obtain about one quart of fairly poor wheat—for example, No. 3 or No. 4—and see how much this sample can be improved by removing the poor kernels of wheat, weed seeds, etc. Divide the quart of seed among the members of your class. Using a short ruler or the large blade of your pen-knife, separate the seed into two piles, one pile of bright coloured, plump kernels, the other pile of poor wheat and impurities. Then proceed in either one of the following ways:

(*a*) When you have sorted out enough good seed, pour it into a small cup until the cup overflows. With your ruler scrape the wheat level with the brim of the cup. Pour the seed into one scale pan of your equal-arm balance. Fill the cup as before with some of the original seed. Pour this into the other pan of your balance. Have you improved the weight of the wheat?

(*b*) Weigh a pint measure (fruit-sealer, milk bottle, etc.). Fill your measure with some of your original wheat. Level off the top. Weigh it again, and calculate the weight of the wheat in the measure. Now select enough good seed, as directed above, to fill the measure. Weigh it, and determine the weight of the seed. Using the weights you have obtained, calculate the weight of a bushel of your original wheat and the weight of a bushel of selected seed. Which weighs more? Has your cleaning been worth while?

REGISTERED SEED IS GOOD SEED.

Many farmers sow registered seed because they know that it produces more profitable crops than can be secured from seed that is not registered. *Registered seed* is seed of very high

Test plots at an experimental farm. (Dept. of Agriculture photo)

quality and purity, harvested from plants that have been selected because they possess valuable characteristics, such as resistance to disease and drouth, ability to yield well, etc. It is called *registered seed* because a record is kept of its origin. The record enables the buyer to learn where and by whom the seed was produced. Registered seed is more profitable to use than seed of unknown origin, because the record guarantees the good qualities of the parent plants.

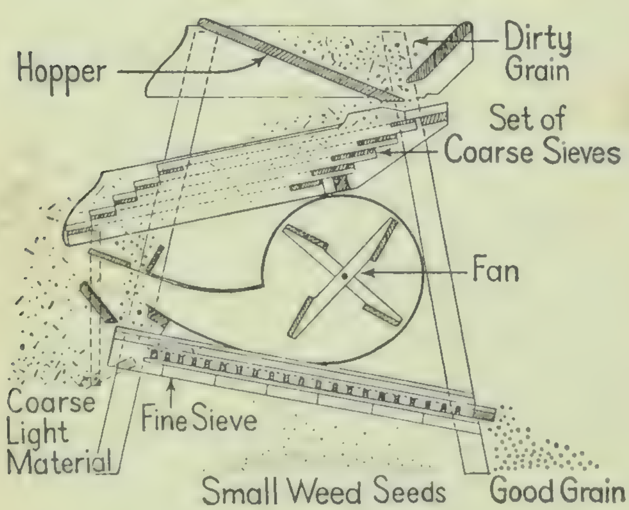
Registered seed is usually produced by agricultural colleges or skilled private growers. It is grown at first in small plots, which during the growing season are carefully rogued; roguing consists of pulling out of the plot all off-type, diseased, or otherwise undesirable heads or plants. The records or pedigrees of registered seed are kept by the Canadian Seed Growers' Association, Ottawa.

Registered seed is good seed because: (1) It is at least ninety-nine per cent pure. (2) Only varieties that have proved to be desirable may be registered. (3) Before being harvested, it must be inspected by a Dominion government inspector, who allows it to be registered only if he finds it to be of high quality and pure. (4) It must be properly cleaned, so that it contains no weed seeds. (5) After the seed is cleaned, it must be sacked, and each individual sack inspected and sealed by a government inspector. The inspector must

attach to each sack a tag on which is shown the variety of the seed, the name of the grower, and other information about the seed in the sack. (6) Before each sack is sealed, the seed must be tested for germination. Registered wheat must germinate at least ninety-five per cent, and oats and barley at least ninety per cent.

HOW CAN A FARMER PRODUCE HIS OWN GOOD SEED?

There is no excuse for sowing seed that has a high percentage of weed seeds and dead seeds in it or that is otherwise unfit for seeding purposes. Every farmer may have seed of reasonably good quality to sow if he wishes. How can he obtain it?



A diagram illustrating the operation of a fanning mill. Study it carefully, and explain how weed seeds, cracked small light shrunken wheat, bunt balls, and other grains are removed from a sample of wheat in the process of cleaning.

1. He may select a portion of the crop in a part of a field where it is particularly good and harvest it separately, to be used as seed. If he does this and then cleans the seed by putting it through a fanning mill, if necessary several times, until a good, plump sample, free from weed seeds and other impurities, is obtained, he is almost certain to have good seed.

2. He may buy a small quantity of good quality registered wheat, sow it, and from the crop produced save enough seed for his seeding requirements; then sow this seed, save more from the crop grown; and so on. This procedure may be carried on and good seed produced for several years. New seed should then be purchased to make a new beginning.

Something to Do

Enlist the help of someone in the community, and practise judging common grains, such as wheat, oats, and barley. A group of three or four samples is large enough to start with. Examine each lot carefully. Keep in mind the characteristics of good seed described on page 179. Award your samples first, second, third, and fourth place. Write out your reasons for your placings, and have them checked afterwards by the person who is coaching you.

If the opportunity offers, enter a grain-judging competition.

Review Questions and Exercises

1. State as many reasons as you can why the best seed available should be used to sow crops.

2. If you were selecting good wheat for seeding purposes, what qualities would you look for?

3. The appearance of seed is not always a safe guide as to its value for seeding purposes. Why?

4. What is the value of a germination test? Describe one satisfactory method of making a test.

5. Outline a method a farmer may use to obtain good seed.

6. What reasons can you suggest for thoroughly cleaning seed?

Test on the Scientific Method

1. In the experiment outlined on page 170, why was it necessary to use a number of seeds in each case rather than only one or two?

2. In parts 1, 2, and 3 of the experiment: (*a*) What conditions were the *same* for both lots of seed? (*b*) What condition was *varied* in each case? (*c*) Why must no more than one condition be varied in any one test? (*d*) Why was it necessary to use two lots of seeds in each part of the experiment?

3. Ted Smith wanted to know if both warmth and moisture are necessary for germination. First he put two beans in moist garden soil in a flower-pot and stood the pot on a window-sill where the sun could reach it. Then, he planted half a dozen corn grains in moist sawdust in a chalk box. He kept the box

in a warm place in a dark corner of the cellar. Both lots of seeds were kept moist. After five days, Ted observed that all the beans and all but one of the corn grains had germinated. He concluded that warmth and moisture are necessary for germination.

(*a*) Was Ted justified in reaching this conclusion?

(*b*) Make a list of all the points about Ted's experiment that you consider were unscientific.

Test your Knowledge

List the numbers from 1 to 16 in your science note-book. After each number write the word *true* or the word *false* to indicate whether each of the following statements is true or false.

1. A seed contains the germ of life and an adequate supply of food to support germination.
2. The embryo of a bean seed is composed of seed-coat, scar, plumule, and root.
3. In corn seeds, food is stored chiefly in the one cotyledon.
4. The endosperm of a corn kernel contains starch.
5. The function of a seed is to provide food for man.
6. Germination is the transferring of pollen from the anther to the stigma.
7. Sunlight is necessary for germination.
8. The addition of rotted manure to a clay soil helps to establish the conditions necessary for quick and healthy germination of seeds.
9. When a bean seed germinates, its cotyledons are pulled above the ground.
10. There is no way by which a farmer can determine the germinating strength of his seed and its fitness for use.
11. When a seed germinates, the plumule emerges from the seed-coat before the root.
12. A wise farmer will sow the cheapest seed he can obtain.
13. Seed of a high quality gives the crop a good start.
14. So long as it is good seed, the variety does not matter.
15. Registered seed is at least ninety-nine per cent pure.
16. Each sack of registered seed is inspected and sealed by a government inspector.

Hugh M. Halliday

O let me live with Nature at her door,
And taste her home-brewed pleasures, simple, glad,—
The beauty of the day, the splendour of the night,—
Not in the great palace halls, great cloister domes,
The smoke of cities and the thronging din,
But out with air and woodlands, shining sun,—
These my companions, this my roof, my home!

—WILFRED CAMPBELL.

CHAPTER EIGHT

CHAPTER 8

POND LIFE

What is an "animal"? How do frogs catch insects? You need to have sharp eyes to see how they do it. Why do fish like to face upstream when resting? Why does a toad's throat swell up like a bagpipe when it "sings"? What insects are good divers and swimmers? What insects build houses in the water in which to lay their eggs? How are water birds fitted for their way of living? What is a "balanced" aquarium?

As you gaze at the quiet surface of a pond in the spring, you may wonder at its stillness, but if you could see beneath its surface and into the mud at the bottom, you would be amazed to find how very much alive its waters really are. In the shallower parts near the edge, you would probably see toads gathering together after their long winter's sleep in the garden. You might also see frogs moving about, minnows gliding this way and that, or crayfish, with their coats of mail, crawling slowly along the bottom. Insects would likely be there in large numbers—skaters skimming over the water in comical fashion, mosquitoes depositing their eggs on the surface, water beetles diving in and swimming under water in search of food, or dragon-flies poised ready to pounce upon their unsuspecting prey. You would also find plants living in the pond, some lying on the surface, some submerged, and others partly in the water and partly out.

As you read on in this book, you will discover many interesting facts about the creatures that live in ponds. You

In ponds like this you will find many odd and interesting forms of plants and animals. See how many different kinds of each you can identify.

will find that some of them live peacefully together, and that others are continually at war with one another.

Something to Do

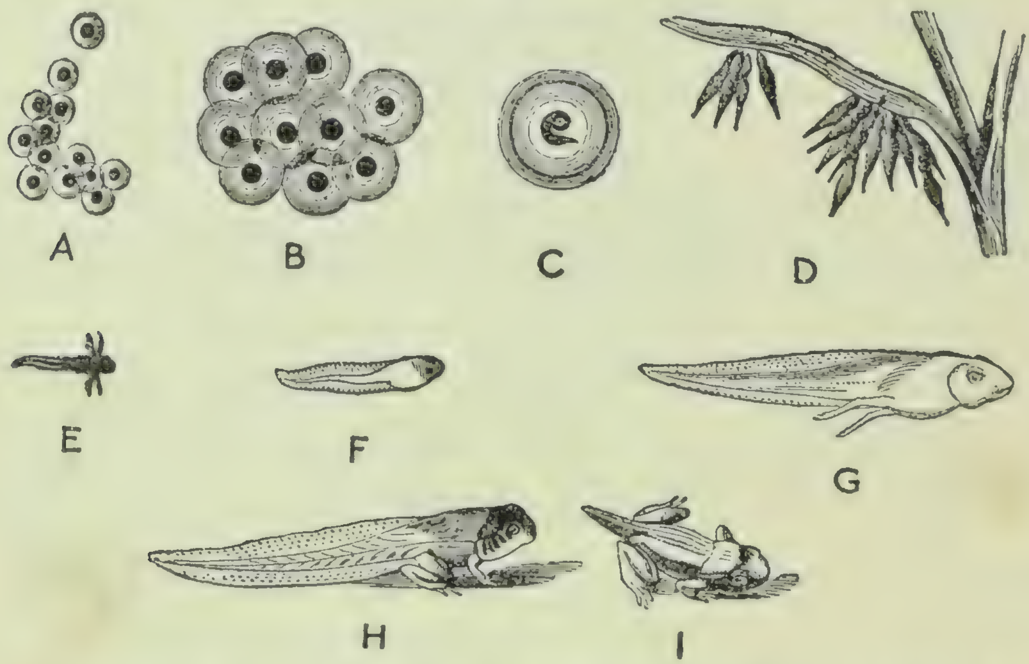
1. Plan to go on a hike to a nearby pond. Discuss with your teacher and classmates some of the things you are likely to see. The introductory paragraph of this chapter will give you some suggestions. Be ready, by studying the illustrations and descriptions on the following pages, to recognize animals, such as tadpoles, giant water bugs, water boatmen, dragon-flies, water striders, mosquito wrigglers, muskrats, killdeers, mallard ducks, as well as some of the plants you will find.

When you arrive at the pond, take a comfortable position and remain as quiet as you can. Keep your eyes and ears open.

2. Take with you on your hike a long-handled dipper or scoop net and a pail, and bring back to school some of the small water animals and plants that you find. *Do not bring more than you can provide with suitable homes.* See page 212 for suggestions regarding the number of animals you should try to keep in a gallon of water.

As you observe and read about pond animals and plants, keep in mind this problem: *How are they adapted, or fitted, to live in their surroundings*? For example: How are frogs adapted for jumping? How are shore birds adapted for

wading and finding their food in shallow water? How are water boatmen adapted for swimming? In order to survive, all animals and plants must be adapted to their surroundings.



Stages in the life-history of the frog: A, eggs before they are laid. B, eggs after they are laid in the water. C, an egg magnified to show the tadpole hatching. D, young tadpoles attached to a blade of grass. E, a young tadpole showing the external gills. F, a young tadpole; its external gills have been replaced by internal gills. G, a tadpole with the hind legs appearing. H, a tadpole with the large tail and front pair of legs now appearing. I, a very young frog. It breathes by lungs. The tail is being gradually absorbed by the blood and carried to other parts of the body for food. (After Brehm)

Something to Do

Make a list of problems, similar to those outlined in the paragraph beginning at the bottom of page 187, dealing with the ways in which various kinds of animals and plants of the ponds are adapted to their surroundings. Try to solve your problems by your own observations. Later, if possible, check your findings by reference to several reliable science books.

THE SPRING CHORUS

Spring is the time of unfolding life, not only in the plant world, but also in the animal world. What a cheerful chorus

comes from the frogs and toads during the evenings of early spring! The frogs have just ventured from their winter quarters—the mud near the pond. The ice has hardly gone before they deposit their eggs on plants or sticks near the surface of the water in ponds or ditches. The eggs are laid in clusters or in irregular-shaped, jelly-like masses. Each egg is surrounded by a globe of clear jelly, which swells up in the water and protects the egg. About two weeks later, toads come out of their deep burrows in the ground and lay their eggs by the thousands in ribbons of clear jelly. A mother

The life-history of a toad. Describe the various stages in the development of this animal.

toad may lay ten thousand eggs or more. The eggs soon hatch into comical-looking tadpoles, which seem to be all head and tail.

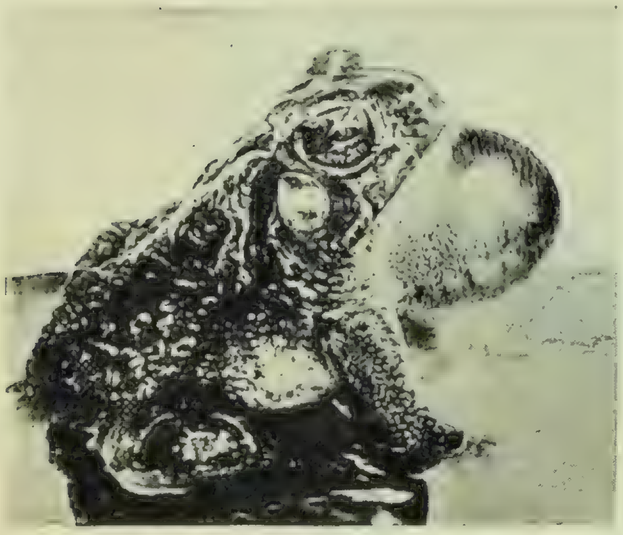
Toads, in particular, are good friends of the gardener, because they destroy many harmful insects. For this reason *we should help and protect them* whenever we find them.

FROGS AND TOADS ARE ADAPTED TO THEIR MODE OF LIFE.

Something to Do

1. *Problem.*—How do frogs and toads develop from eggs?

Gather frogs' and toads' eggs from ponds and ditches in early spring at the time when the frogs are "singing." Scoop them up with a scoop net or a long-handled dipper. Put them into a glass jar filled with pond water containing pondweed and sticks. Keep the jar in a moderate light. Remove eggs that die (turn white).

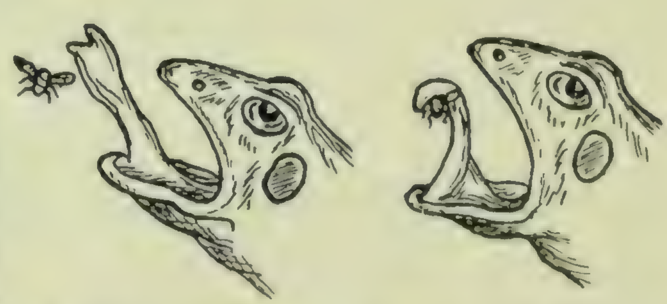


A toad singing. (Doubleday, Page & Co. photo)

How the eggs hatch.—Observe the shape of an egg within the jelly. Notice that it is dark on top and light below. The dark surface absorbs warmth from the sun. Of what advantage is this? Watch for the first movement in the jelly. How long is it from that time until the tiny animal, or *tadpole,* as it is called, wiggles out of the jelly?

How a tadpole becomes a frog or a toad.—The following observations may be made by watching the tadpoles in your aquarium or in a pond. What is the shape of a tadpole? Notice that for the first day or two the young tadpole usually attaches itself to a stick or a leaf. During this inactive stage it lives on the yolk of the egg, just as a newly hatched chicken does. Watch for the appearance of feather-like *external gills,* which project into the water from the sides of the head. These are special organs for respiration. How many of them are there? They are soon replaced by *internal gills,* which develop in the throat region. The tadpole now breathes like a fish: water passes in through the mouth, over the gills, and out through a small opening in the left side of its head. Oxygen is taken out of the air in the water as it flows over the gills.

Watch for the appearance of legs. Which appear first, the front limbs or the hind? Notice that the tail gradually shortens, as the food stored in it is absorbed into the body of the developing frog or toad. Observe that the tadpole now comes to the surface to breathe, using its lungs more and more instead of its gills. How long does it take for an adult to develop? Toads and some



A frog catching an insect with its sticky tongue. (Drawing by courtesy of Calvert and Cameron)

frogs mature in eight or ten weeks, but bullfrogs do not reach the adult stage until the following summer.

NOTE.—If your tadpoles have not developed into frogs before school closes for the summer, be sure to provide for their care during the vacation, or take them back to their home in the pond.

Make a record of your observations.—Write in your science note-book a complete story of the development of a frog or a toad. Your own personal observations should form the basis of your story.

Make a page of drawings to illustrate your story. If possible, make them from the specimens themselves. Include the following: (1) a cluster of eggs, (2) a young tadpole showing the external gills, (3) the tadpole after the external gills have disappeared, (4) the tadpole when the hind legs have appeared, (5) the tadpole when the front legs have appeared, (6) the adult.

2. *Problem.*—How do adult frogs live?

Adult frogs may be kept in your school aquarium or other suitable container. Study them, and find the answers to the following questions: How do they travel? Can they walk? How are they fitted for swimming? for jumping? How do they catch insects? Have they necks? Watch them breathing. What movements do you observe? Are frogs easy to hold? Is their slipperiness an advantage to them? What colours are frogs—above and below? How do they escape their enemies? Where do they spend the winter months?

An excellent example of protective colouration. In what other ways can a frog escape its enemies? (Doubleday, Page & Co. photo)

"FISH STORIES"

Fish are remarkable creatures. They can glide through water as readily as a bird sails through air—a wonderful feat, since water is about eight hundred times as heavy as air and therefore offers much greater resistance.

In some parts of the world there are very queer fish—the flying fish, for example, which can sail for short distances through the air. But we do not need to go far afield to gather good "fish stories"; the fish to be found right in our own waters are as different from one another in size, shape, and habits as day is from night. The tiny stickleback, for instance, never grows larger than two or three inches in length. Sturgeon, on the other hand, frequently weigh from two hundred to three hundred pounds.

The stickleback builds a nest in the water, and the male, rather than the female, guards the eggs and the young. Some fish—the whitefish, for example—lay their eggs in the fall, others in the spring. Whitefish eggs require about six months to hatch. The eggs of the pickerel, on the other hand, when fertilized, hatch in from three to six weeks, depending upon the temperature of the water. The female pickerel lays, on an average, thirty-seven thousand eggs. Many lively tales of the trout—particularly the rainbow, the Loch Leven, and the brown trout—could be gleaned from the angler who finds his way into our provincial parks, where these fish abound.

HOW ARE FISH FITTED TO LIVE IN WATER?

Something to Do

1. *Problem.*—How do fish travel?

Materials.—Minnows, young perch, shiners, or a goldfish in an aquarium containing green water plants. (For suggestions regarding the preparation of an aquarium see pages 209-212.)

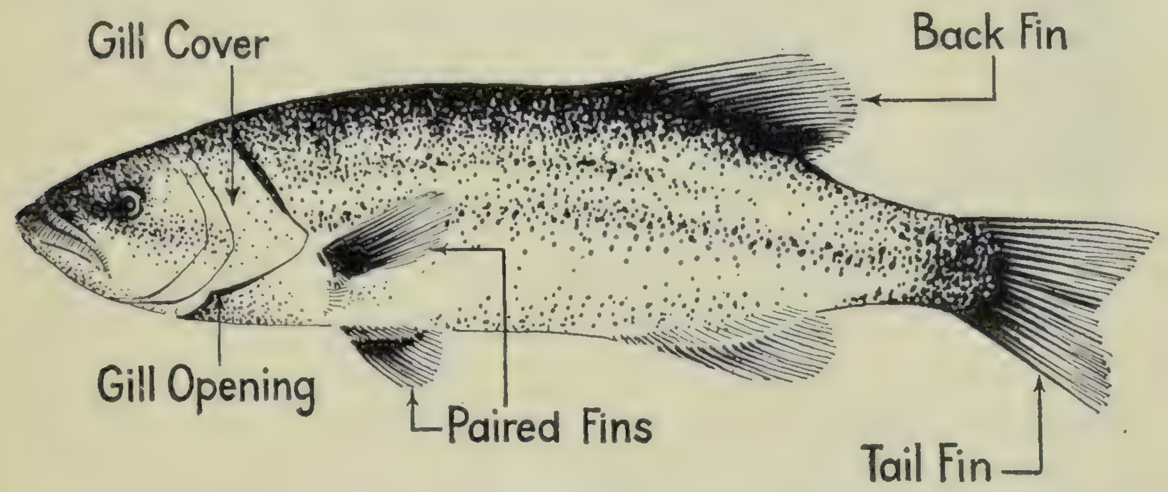
Observe the smooth, tapering, double wedge-shaped body, with scales that overlap like shingles from head to tail. Notice, also, that the body is covered with a substance that makes it very slippery. Do you think that a fish offers much resistance to the water?

Study the *fins*. Notice that a fish has two pairs of side fins. These correspond to front and hind legs. How many fins are there along the middle line of the back? How many are there along the middle line of the under side? Notice that the bony

framework or fin rays point towards the hind end of the fish. Why? The tail and tail fin have much to do with the locomotion of a fish. Watch the fish closely to see how it moves forward and keeps its direction. Try to find out the uses of (*a*) the paired fins, (*b*) the fins along the middle line, (*c*) the tail fin. Which are used to propel the fish forward? Which are used for backing up? for "brakes"? Which fins are used to balance the fish?

2. *Problem.*—How do fish "breathe"?

Materials.—A freshly killed fish of good size (for observing the parts); a living fish in an aquarium (for observing the movements).



A perch showing the fins and other external parts. Find them on a fish of your own.

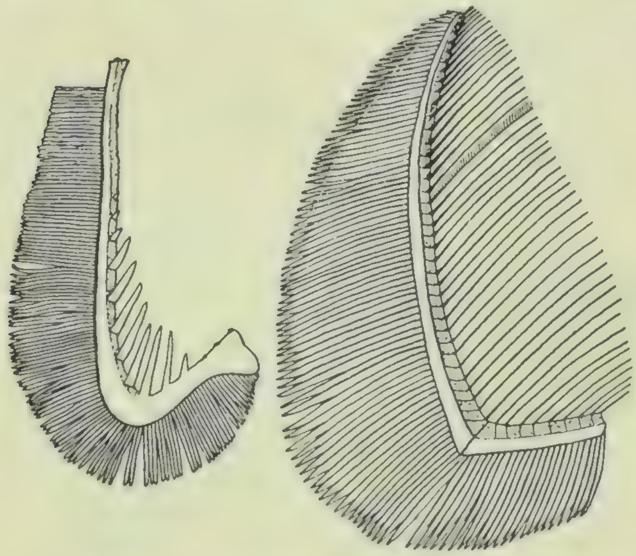
Like all other living things, fish require oxygen for respiration. How do they obtain it? We cannot breathe under water, but for this purpose fish have special organs, called *gills*. Lift up the gill cover of a freshly caught fish, and examine the gills. How many are there? Each gill consists of a bony, J-shaped *arch*, from the outside of which project many soft, fleshy *filaments*, or threads, and from the inside a number of short, spiny *rakers*. Notice how red the filaments are; the redness is caused by the blood circulating through the filaments. Open the mouth of a fish, and notice the passageway between the mouth and the gill opening at the side of the head. What purpose does it serve?

Now observe a living fish as it bites at the water and appears to swallow it. Notice that there are two movements: (1) the

opening and closing of the mouth, and (2) the opening and closing of the gill cover. Try to discover whether the gill cover opens at the same instant as the mouth or a trifle later.

Make a drawing (side view) of a living fish, and label the parts.

When a fish's mouth is opened, water enters and fills it. When the mouth is closed again, water is forced over the gills and out through the gill opening. Oxygen, which is dissolved in the water, passes into the blood that flows through the thin-walled, thread-like filaments of the gill. At the same time, carbon dioxide passes out of the gill into the water. Thus the blood is purified, getting rid of its wastes and taking on a fresh supply of oxygen to be carried to each cell for the purposes of respiration.



Gills of a fish. Observe the gill rakers, the gill arch, and the gill filaments in each case. (Drawing by courtesy of Calvert and Cameron)

Review Questions and Exercises

1. When we hear frogs and toads "singing" in the spring, we say, "The frogs and toads have returned." Where have they been during the winter?

2. Where and when would you look for frogs' eggs? How would you distinguish them from toads' eggs?

3. How are the eggs of frogs and toads fitted to hatch without attention from the mothers?

4. Describe how a tadpole becomes a frog or a toad. What is its first food? What is the first change that takes place? Which pair of legs appear first? Why does the tail gradually shorten?

5. Are frogs and toads helpful or harmful? Why?

6. How are frogs and toads adapted to their ways of living? How do they catch their food? How do they escape from their enemies? How do they travel on land and in water?

7. A fish is specially fitted to live in the water. How does it swim, breathe, and capture its food?

HOW ARE ANIMALS CLASSIFIED?

Mary Todd was reading a list of the names of animals that are useful to man. In the list she found, among others, horses, cows, sheep, pigs, birds, toads, and earthworms. "What a queer list of *animals!*" she exclaimed. "Why are birds, toads, and earthworms included?"

Perhaps you too are surprised to find certain names in the list of animals in the above paragraph, but that is only because we do not ordinarily speak of birds, toads, earthworms, and insects as animals. Scientists, however, place *all* living things in two groups—*plants* and *animals*. Now ask yourself: "Are birds plants? Are toads, earthworms, and insects plants?" At once you will answer: "No, they are not plants." If they are not plants, it follows, then, that they are animals. In the sense in which the scientist uses the term, frogs and toads are animals; fish are animals; and insects, spiders, snails, crayfish, and many other creatures are animals.

Both groups—plants and animals—are divided again, by scientists, into a number of classes. Animals, for example, are classed as mammals, birds, reptiles, amphibians, fish, insects, etc.

Among the inhabitants of ponds, the beaver and the muskrat are probably the best known animals of the *mammal* group. All mammals have hair or fur on their bodies. Mother mammals feed their babies milk. Mammals are warm-blooded; that is, their body temperatures do not vary unless they are ill. No other animals have all three of these characteristics.

A body covering of feathers is the chief characteristic of the class of animals known as *birds*. Like mammals, birds

are warm-blooded. Their body temperature remains the same regardless of the temperature of their surroundings.

Reptiles include turtles, crocodiles, snakes, and other creatures whose bodies are covered with scales. They are cold-blooded; that is, their body temperatures vary, being usually about the same as the temperature of their surroundings. The reptiles are generally regarded as an unpleasant lot, but several, such as the garter snake, are our friends.

Frogs, toads, and their relatives are called *amphibians* (from a Greek word meaning "living a double life") because they live part of their lives in the water and part on land. Most of the amphibians breathe with gills when they are young and with lungs after they are full-grown. They are cold-blooded.

Fish, as you know, live in the water. They breathe with gills; they are cold-blooded; and their bodies are covered with scales.

Mammals, birds, reptiles, amphibians, and fish have backbones and bony skeletons. There are other groups or classes of animals that do not have backbones and bony skeletons. These groups include insects, spiders, crayfish, crabs, snails, clams, earthworms, starfish, sponges, and other animals.

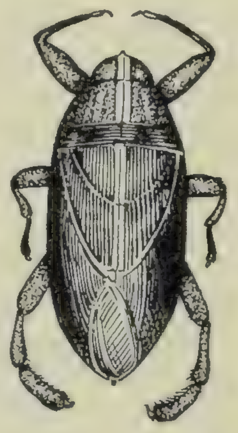
Insects are animals that have six legs. Their bodies are divided into three parts. They "breathe" by means of spiracles and air-tubes. No other animals possess any of these characteristics. Any one or all of them, therefore, may be used as a means of identifying insects. Spiders, for example, are not insects, because they have eight legs. Are the many-legged centipedes insects? Why?

INSECTS THAT LIVE IN PONDS

Many hundreds of species of insects spend part of their life under water.

One of the largest water insects is the big, brown *giant water bug,* which spends most of its life in ponds. This insect

has a large, flat, grayish or brownish body and hind legs that are highly developed for swimming. It rests at the bottom of a pond, hiding under sticks and stones as it watches for a minnow, a tadpole, or a small frog to come its way. It seizes its prey with its clasping forelegs, stabs it with its deadly beak, and injects benumbing poison into the wound. Then it proceeds in a leisurely way to suck the blood of its unfortunate victim. The giant water bug lays about sixty tiny brown eggs on leaves and grass around ponds. The young live entirely in the water, pass through a long-legged nymph stage, and finally moult and come forth as winged adults. One of the smaller kinds of water bugs, however, lays its eggs on the back of the male, which unwillingly serves as an incubator.



A giant water bug, or electric light bug. It is a large, flat, gray or brown coloured bug.

Another large water insect is the *water beetle* or diving beetle, of which there are many different kinds. One of the most fearless and aggressive is the yellow-bordered water beetle, which is more than an inch long and three-quarters of an inch wide. It is almost black with a dark olive-green lustre. It has two pairs of wings. The hard, shell-like cover wings have a sharply defined, dark yellow border, and the flight wings, which fold under the cover wings when not in use, are strong and transparent. The hind legs are well developed, and are furnished on the inside with a dense line of very stiff bristles, which help to make the beetle an excellent swimmer. The water beetle can stay below the surface for a long time. To obtain a fresh supply of air, it comes to the surface and protrudes its abdomen into the air, the head end remaining in the water. Water beetles leave the water in the evening; therefore, if they are kept in an aquarium, the top should be covered. They should also be provided with plenty of food—insects and small fish.

Giant water bugs and water beetles may often be found hovering about street lamps at night. They are quite harmless—you need not be afraid to observe them closely.

A water boatman about twice its natural size. Notice the boat-shaped body, and the hind limbs in the position of oars. This insect is a back swimmer.

The *water boatman* takes its name from the fact that it is shaped like an inverted boat. It is less than half an inch long. It propels itself by means of its flattened hind limbs, which are fringed with hairs and stand out in the position of oars. It carries its air supply in its wings. One kind of water boatman swims on its back and seizes its prey from below. Watch for water boatmen when you visit ponds.

The gaudy *dragon-fly* lays its eggs in the water. The young dragon-fly, or nymph, which hatches from the egg, spends three years in the water before it changes to a full-grown dragon-fly; it then lives in the air for the rest of its life—about three weeks. The nymph rests at the bottom of the pond, patiently waiting to pounce upon and devour any animal it can overpower. When about to attack, it uncoils a strange weapon that covers the front of the head and represents the lower lip. The adult dragon-fly feeds upon flies, mosquitoes, and other insects, which it catches on the wing, swooping down upon them like a hawk upon its prey.

An adult dragon-fly.

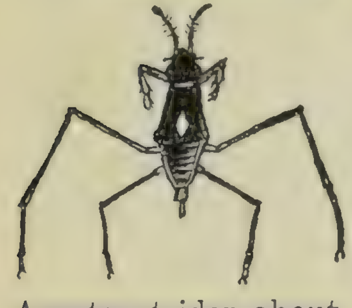
Caddis flies are not so easily found. They spend their "caterpillar" stage at the bottom of ponds and streams, where most of them construct "tubular

houses" out of shells, gravel, sticks, etc., to conceal their soft, defenceless bodies from fish and other enemies. The adults have wings and are commonly called trout flies.

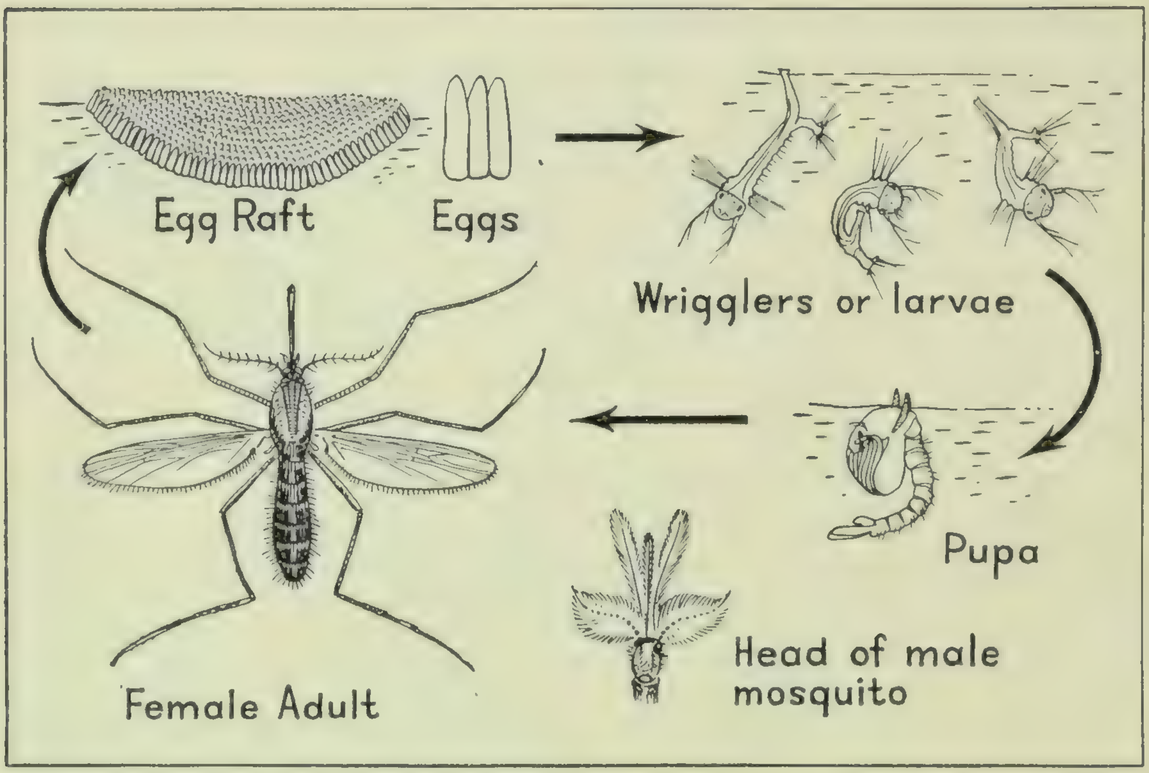
A May fly enlarged. Notice the small hind wings and the slender filaments projecting from the abdomen. These insects are an important source of fish food.

May flies have several peculiarities. The front wings of the adult are very large in comparison with its rear wings. Its mouth parts and digestive tract are useless; consequently, the adult never knows the joy of eating food. Projecting from the end of the abdomen are two or three long, slender threads. The May fly lays its eggs in water. The eggs hatch into long-legged larvae, or caterpillars, which swim or crawl among the water plants on which they feed. In their next stage—the pupa stage, in which they are enclosed in cases—these insects, unlike some kinds, are active. When they are ready to change to the adult form, they float on the surface, the skin along the back splits open, and the winged insect emerges and flies to shore. Some adult May flies live only a few hours, and none live more than a few days. They remain quiet during the day but are active in the evening, often swarming around electric lights.

Water striders or skaters are very amusing. They can skate over the water and never get wet. If you wish to know how they do it, try to float a dry sewing needle on water by carefully lowering it to the surface. It can be done. So, too, can a water strider, keeping his padded feet dry, skim over the surface of a pond in summer as readily as a boy can glide over the icy surface of the same pond in winter.



A water strider, about twice its natural size. This long-legged insect can skate on water.



The life-history of the common mosquito. Have you ever seen the wrigglers or pupae in a pond or rain-barrel?

MOSQUITOES ARE TROUBLE MAKERS.

Mosquitoes lay their *eggs*, from two hundred to four hundred at a time, in raft-like clusters on the surface of quiet bodies of water. The most common breeding places are shallow, stagnant pools of melted snow, rain-barrels, old tin cans full of water, sloughs, etc. In warm, favourable weather, the eggs hatch in about twenty-four hours. The *larvae*, or wrigglers, as they are called, swim around vigorously in search of food. They must come close to the surface of the water for air, which they obtain by extending a tiny air-tube up through the water. In about seven days, they enter the *pupa* stage. Mosquito pupae differ from many pupae in that they move around freely. They remain in this stage for two days or more. Then the *adult* mosquitoes emerge, and climb up on the pupa cases, which they use as rafts until their wings are dry and ready for flight.

Something to Do

Confine a few mosquitoes under a glass tumbler, and observe their chief characteristics. How many wings have they? Notice the long legs. How many parts are there to the body of a mosquito?

Only the female mosquito annoys us. It bites us and sucks our blood. The male mosquito feeds on the nectar of flowers and is harmless. Some mosquitoes, not found in this country, spread malaria and yellow fever. Though the common mosquitoes with which we are familiar do not spread disease, they are such pests that we should all do what we can to reduce their numbers.

HOW TO CONTROL MOSQUITOES

1. See that no rain-barrels or other receptacles, such as water-troughs, tin cans, pails, eaves-troughs that have been plugged up or have sagged, are left standing full of water in which mosquito eggs can be laid. The number of mosquitoes that can be produced in one rain-barrel is surprising.
2. When possible, drain or fill in all shallow pools of water.
3. When pools cannot be drained or are too large to be filled in, cover the surface of the water with a thin layer of kerosene or specially prepared mosquito oil. The oil spreads over the water and smothers the larvae and pupae. Oiling must be done about four times during the summer, and must be commenced early. It has been found that mosquito eggs will hatch in water at a temperature of from thirty-five to forty degrees Fahrenheit. How much is this above freezing temperature? Delay in oiling means a batch or two of mosquitoes in the spring.

Something to Do

Secure a few mosquito wrigglers from a pond or slough. Pour a thin layer of oil over the surface of the water. Carefully observe what happens to the larvae. Account for the result.

4. Protect the birds, such as nighthawks, that eat large numbers of mosquitoes. Help them to help us in our efforts against these pests. Fortunately mosquitoes have many other natural enemies. Dragon-fly larvae, water beetles, and small fish feed upon the wrigglers and pupae, and adult dragon-flies prey extensively upon full-grown mosquitoes.

Many places have waged successful wars against mosquitoes and thus have proved that it is possible to keep them in check. Mosquitoes fly only about five or six miles. Therefore, if proper control measures are applied to the district within this distance around a community, there will be few mosquitoes to annoy the residents.

Something to Do

Make a study of water insects.

Using a dip net, secure some mud, leaves, and grass from the bottom of a slough, pond, or lake. Carry this material home in a pail, along with some pond water. Pour enough into a large glass jar to half-fill it, and cover the top of the jar with cheese-cloth to prevent the escape of adults that hatch. *Do not allow the water in your aquarium to become stagnant.* See page 210 for suggestions regarding its arrangement and care.

Put into the jar some plant stems, up which the dragon-fly nymphs may climb to make their last great change—the change into the adult form. This change occurs in the evening; so watch very closely if you wish to see this interesting process.

If you secure some caddis larvae, provide them with coloured beads, and watch them build the beads into houses with novel effect.

Watch the mosquito eggs hatch and go through the larva and pupa stages.

WATER SPIDERS

Little scarlet water spiders, or watermites, are quite common in early spring. They are easily distinguished from insects because they have four pairs of legs. Some water

spiders can live under water for hours at a time. They construct a soft, silky, cup-shaped cocoon under water and then carry air down from the surface to fill it. Spiders live and rear their young in this miniature "diving bell." Watch for them in the water when you visit ponds in the spring.

SNAILS ARE SCAVENGERS.

The slow-moving, shell-covered snail is valuable in an aquarium. It consumes refuse of all kinds and also keeps the glass clear of the green scum-like plants that are known as algae. Snails' eggs provide food for the fish.

Something to Do

Secure a number of snails from a pond to help to "balance" your aquarium. Learn to recognize the different kinds, and to know their habits and modes of life.

Snails are interesting and useful animals in an aquarium. A snail has only one foot. How does it move? How does it use its shell?

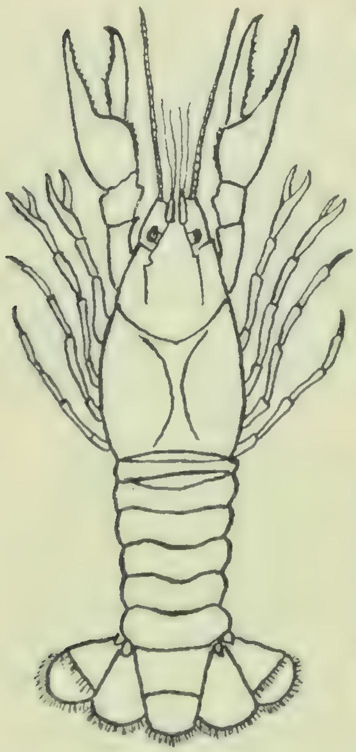
FRESH-WATER SHRIMPS

Water shrimps are rusty red in colour and about the size of an acorn. Some have shells; others have not. They breathe by means of many pairs of plume-like gills. They are very abundant in ponds and ditches in the spring. Their eggs drop to the bottom, dry up with the pond, and hatch with the rains of the next spring.

CRAYFISH SHED THEIR COATS OF ARMOUR.

Like the water shrimp, the crayfish belongs to a class of animals called Crustaceans (crŭs-tā′shŭns). Its skeleton is on the outside of its body, and each year it sheds this hard protective covering and grows a new one in its place. Have you seen these discarded suits of armour lying along the shore of a pond or lake? The large pincers look very dangerous. Notice that the crayfish has five pairs of legs and two pairs of

antennae, or feelers. It is thought that it can smell and taste by means of the feelers. It can swim backwards with considerable speed. Why does it not swim forwards? The crayfish has many peculiarities; perhaps one of the most striking is that its eyes are on the ends of short stalks.



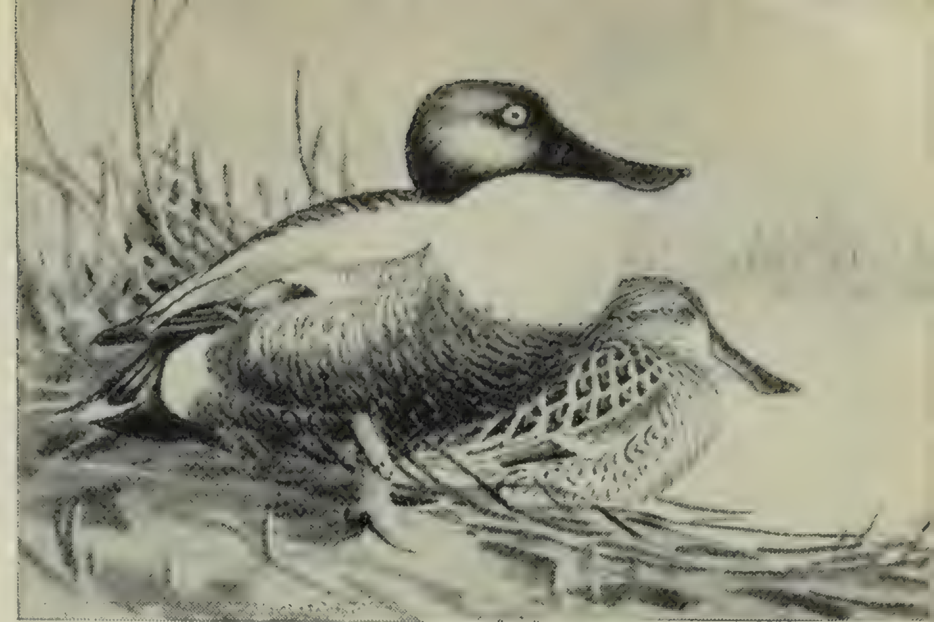
A crayfish. Notice the large pincers, the many-jointed legs and feelers, and the broad tail fin.

Something to Do

Bring discarded crayfish skeletons to school for study. If possible, secure a living specimen, and keep it in an aquarium for observation purposes.

Review Questions and Exercises

1. Name several kinds of animals that have no backbones or bony skeletons.
2. Name ten animals that are not mammals.
3. In what ways do spiders and insects differ? In what ways are they alike?
4. How do mammals, birds, and fish differ from one another? How do they resemble one another?
5. Select one or two of the following water insects, and by means of a labelled drawing prepare a description that would enable a schoolmate to recognize it: giant water bug, water beetle, water boatman, dragon-fly nymph and adult.
6. Name several water insects not mentioned in Exercise 5.
7. How do mosquito pupae differ from most insect pupae? Briefly describe the other three stages in the life of a mosquito.
8. Mosquitoes can be controlled in many localities. Plan a mosquito control campaign. Briefly outline the various methods of control that should be given consideration.
9. Tell several interesting things about one of the following animals: water spider, snail, fresh-water shrimp, crayfish.
10. Select one pond animal, and explain how it is adapted to its surroundings.



Shoveller ducks are easily identified by their shovel-like beaks. (Department of Natural Resources photo)

POND BIRDS

Jack Arthur and Bill Williams were on a "scouting" trip. The "enemy" was the army of living things that make their home in a nearby pond. The boys enjoyed seeing how close they could creep to shore birds or ducks in order to have a good look at them as they hurried about busily. It required good scouting tactics too, because noise or sudden movement sent the "enemy" flying away in a flash.

What was that? A big bird was swimming on the pond. Jack and Bill were sure it had not been there yesterday. What kind of bird was it? The boys observed its green head, the white ring around its neck, and the purple, white-edged band on its wings. They made quick notes in their field note-books and took accurate "mental photographs."

On their return to school, they searched the bird book and identified their bird as a male *mallard duck*. You may imagine how pleased the boys were. They were the first in their school to see the mallard upon its return from its winter trip to the south.

You, too, can enjoy observing and studying pond birds. Try to learn how each bird you see is adapted to its way of living.

Ducks, with their boat-shaped bodies and webbed feet, are wonderfully fitted for swimming. If you are observant, you may see not only the beautiful *mallard* but also canvas-backs, bluebills, shovellers, pintails, and many other ducks. The *canvas-back* is a large bird. It is light coloured over the back and has a red head with sloping forehead and long beak. The *bluebill* is smaller. The front part of its body appears

These eared grebes are diving birds. Note the spray of golden-coloured feathers on their cheeks. You may find these birds and their nests on many ponds.

Western willets are common around ponds and sloughs. Watch for them. How are they adapted to secure their food and escape from their enemies? (Photos by Bureau of Publications, Regina)

black, while the remainder is white. The *shoveller* is green, white, and brown. It is a large bird with a broad bill shaped like a spoon or a shovel. The *pintail* duck is large also. It is gray and white. It has a long, slender neck, and a long, pointed tail.

Shore birds are very active creatures. They have long legs and bills that fit them for wading and securing food in the shallow water of the borders of ponds. The more common shore birds are killdeers, western willets, and yellow-legs. The *killdeer* is medium sized. It is pure white below, with reddish brown on the rump and tail and two black breast bands. The *western willet* is a large gray bird, with white rump and tail. When in flight, it shows a prominent white bar across its dark wings. The *yellow-legs*, as its name indicates, has long yellow legs. Its body is covered with a very fine pattern in black and white.

Another beautiful bird that makes its home around ponds is the *red-winged blackbird*. It has a jet black body and brilliant red shoulders. Watch for it when next you visit a pond.

PLANTS THAT THRIVE IN WATER

Plants that grow in water are either free swimmers or rooted plants. *Free swimmers* are not rooted to the bottom and are completely supported by the water. Some, such as the duckweed, live on the surface, while others—for example, the elodea—are completely submerged. *Duckweeds* are the smallest of all flowering plants. They float freely on the surface of ponds. Each plant consists of a tiny leaf-like part from which one or several roots extend down into the water. Duckweeds are sometimes very plentiful and cover the water like a green blanket. The *elodea*, or water weed, has very short, narrow leaves. It is common in the bottom of slow-moving or still water. Many *algae* are also free swimmers. These plants are often so small that you cannot see one by itself without a microscope. Algae are sometimes called pond

scum, because when they are numerous, they may completely cover the surface of parts of a pond.

The leaves of some *rooted water plants* are entirely submerged. Those of others, the *water lily* for instance, rest on the surface. *Pondweeds* have narrow, grass-like underwater leaves as well as oval-shaped leaves that float on the water. Their flower spikes may extend above water. Still other plants are rooted in soil, but their stems rise above the water, and their leaves are exposed to the air on all sides. Examples of this type are cat-tail, bulrushes, reed grasses, and arrowhead. The *cat-tails* are from four to six feet tall, with long, slender leaves. In the fall, the soft brown, cylindrical flower spikes are very conspicuous. *Bulrushes* are also tall, grass-like plants. *Reed grass* is a large, leafy grass, which reaches a height of from four to six feet or more. It has large, rather soft, spreading pannicles or flower clusters. *Arrow-head* has showy, pure white flowers of three petals. Most of its leaves are large and arrow-shaped.

Something to Do

1. Plan a "scouting" trip like that described on page 205. What equipment had Jack and Bill to help them remember what they observed? How did they move in order to get as near to the "enemy" as possible? Try to be the first in your school this spring to see one of the birds described in this chapter.

2. Visit a nearby pond to examine the plants growing there. How are they fitted for their life in the water? Bring back some plants in a pail for further observation at school and for your school aquarium.

AN AQUARIUM FOR YOUR SCHOOL

A vessel prepared as a home for plants and animals that live in the water is called an *aquarium*. When there are just enough plants in the aquarium to supply sufficient oxygen for the animals and just the right number and kinds of animals to furnish the plants with the carbon-dioxide they require, the

A corner of a pond showing: A, arrow-head; B, cat-tails; C, reed grass; D, duckweed; E, pondweed; F, elodea. In the left centre are water lily flowers and leaves.

aquarium is *balanced*. An aquarium in your school will provide you with an opportunity to study first-hand many different forms of aquatic life and to make your own observations regarding them. When you establish an aquarium, be sure that you do not neglect the animals you put in it.

What kind of aquarium shall it be? A quart sealer makes a small but inexpensive aquarium for school observations. True, you cannot keep much material in one jar—one small fish and one water plant would be plenty; but by using a number of sealers, you may have fish, tadpoles, dragon-fly nymphs, and other forms of pond life all under close observa-

tion at one time. A wide-mouthed battery jar holding a gallon or so of water also makes a suitable aquarium. If you wish to have a larger aquarium, you may construct a rectangular one with glass sides and metal bottom and frame. Failing these, you may keep small fish and other aquatic animals in tubs or boilers in the basement.

A quart-jar aquarium stocked with pond water, pond weeds, and two tadpoles. Similar material can be found in almost any pond in spring.

HOW TO ESTABLISH A BALANCED AQUARIUM

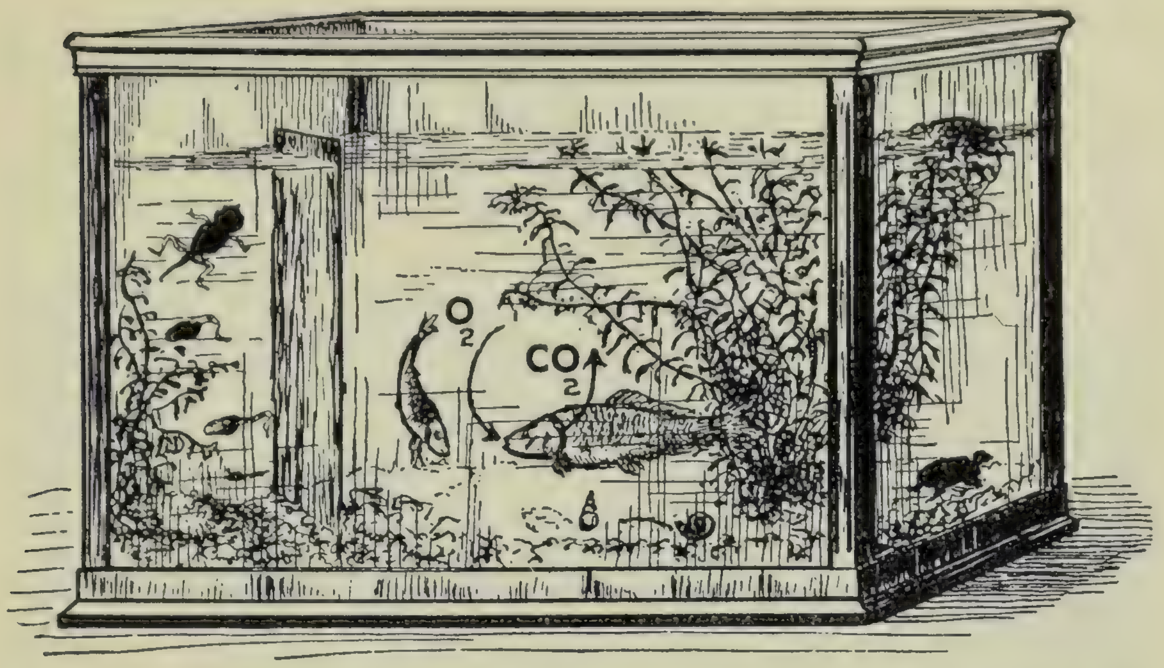
Experience will teach you how to balance an aquarium. Follow the instructions given below, and keep trying until your results are satisfactory.

1. Clean the container thoroughly, removing all dust, etc., from the glass.

2. Thoroughly clean enough sand to fill the bottom of the container to a depth of from one to two inches. The sand may be put in a pail and washed several times with water to get rid of all the dirt. Find some attractively coloured pebbles; clean them thoroughly, and place them in the bottom of the aquarium with the sand.

3. If the aquarium is fairly large, it should be placed in its permanent position before being filled. It may be located directly in front of a north window, or near any window that does not receive direct sunlight for more than one or two hours daily. Too much sunlight causes the growth of green algae on the glass.

4. After placing the clean sand and pebbles in the bottom, carefully fill the aquarium to a depth of about six inches with water. Clear pond water or water that has stood for several days in an open container is best.



A balanced aquarium. Notice that a partition separates the tadpole from the fish and the turtle. Why? Oxygen (O_2) set free by the plants is taken into the gills of the fish, and the carbon-dioxide (CO_2) given off from the gills is used by the plants. Explain why.

5. Then obtain some green plants from ponds, and set them in the aquarium. Use plants sparingly; too many plants will cause the water to become cloudy. Plants with roots require to be rooted in the sand. Plants that are free swimmers, such as elodea, should be weighted down with a wire or other form of sinker.

6. Add more pond water until the aquarium is about two-thirds full. Be careful not to disturb the sand.

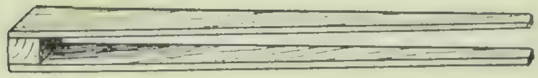
7. Let the aquarium stand for a few days to allow the plants to become established and the water to become clear.

8. Stock your aquarium with animals that agree. Goldfish, shiners, suckers, and frog and toad tadpoles may be kept together, but perch, pickerel, turtles, frogs, water beetles, and crayfish are better kept by themselves. Include some snails to act as scavangers and to help to keep the glass free of algae. One small clam will prove an interesting addition to your aquarium. A baby turtle, measuring about one inch across the shell, will be a source of entertainment, but it must be watched carefully, as it may molest the other small animals. For fish you can get

minnows, shiners, sticklebacks, or catfish from the pond or lake, or goldfish from a florist shop. If you wish to balance your aquarium, do not use too many fish. Do not overstock your aquarium. A gallon of water can accommodate a small fish (about one inch long), a tadpole or two, a snail, and a few water insects.

9. Watch your aquarium. If the water becomes cloudy, remove some of the plants. Remove, at once, any animals that die, and also all dead parts of plants.

10. Feed the animals sparingly. The fish will obtain much of their food from the plants, and a very little fish food every day or two is all that they require. Turtles will eat flies, small bits of earthworm, etc. Snails and clams need not be fed at all, they can shift for themselves in a balanced aquarium. Tadpoles at first feed upon microscopic plants. To supply these, once a week add a little mud or a stone covered with slime from the bottom of a pond. Later, add pieces of hard-boiled egg now and then.



Wooden forceps for removing objects from the aquarium. The block is an inch thick. Roundhead screws are best for fastening the side pieces on.

Review Questions and Exercises

1. How are ducks adapted for swimming? Name two common wild ducks.
2. Name two shore birds, and explain how they are adapted to make their living in shallow water.
3. Make a list of under-water plants. Describe one of them.
4. How can cat-tails be distinguished from reed grass?
5. Name a water plant with showy white flowers. Describe its leaves.
6. When is an aquarium said to be balanced?
7. How would you proceed to establish a balanced aquarium?

Test your Knowledge

Rewrite each of the following sentences in your science notebook, filling in the blanks with the word or words that correctly complete each statement.

Black terns are common around ponds and marshes of the prairies. They are dark slate-gray in colour with black heads. (Department of Natural Resources photo)

1. Frogs' eggs hatch into small animals called tadpoles ______, which breathe by means of gills ______.

2. Frogs are adapted for swimming by having powerful hind ______ limbs with webbed ______ feet.

3. We should protect the toad because it eats insects ______, which damage our gardens.

4. A fish is fitted for living in water in the following ways: (1) ______, (2) ______, (3) ______.

5. Each gill of a fish consists of ______, ______, and ______.

6. When water passes over the gill, ______ passes from the water into the blood in the gill ______, and ______ passes out into the water.

7. Five classes of animals that have backbones are: ______, ______, ______, ______ and ______. Three classes that have no backbones are: ______, ______, and ______.

8. Mammals have ______, reptiles have ______, and fish have ______ on their bodies.

9. Five insects that spend part of their lives in water are: _______, _______, _______, _______, and _______.

10. A layer of oil on the surface of the water smothers the _______ and _______ of the mosquito and is, therefore an effective control measure.

11. Mallard ducks have _______ coloured heads. Canvas-backs have _______ coloured heads. Shovellers have _______-shaped bills. Pintails have _______ tails.

12. Killdeers have two _______ breast bands. Western willets are _______ in colour. Yellow-legs are almost _______ and _______ in colour.

13. Duckweeds consist of a tiny, floating _______ part. The elodea has very _______, _______ leaves. Cat-tails have a soft, _______ coloured, _______-shaped flower head. Reed grass may grow to a height of _______ feet or more.

14. Plants are necessary in a balanced aquarium to generate _______ for the _______ population.

15. Snails are useful in an aquarium because they act as _______ and help to keep the glass free from _______.

Dept. of Agriculture

I will go root away
The noisome weeds, that without profit suck
The soil's fertility from wholesome flowers.

—SHAKESPEARE.

CHAPTER NINE

CHAPTER 9

PLANT ENEMIES MUST BE CONTROLLED

Our fight against plant enemies has been described as one of the greatest wars of all times. Name some plant diseases, insect pests, and weeds that feed upon our crops or rob them of their food supply. How can you protect your crops or your flower garden from these enemies? Nobody likes weeds. Why? What makes a plant a weed? What can you do to help to get rid of weeds?

Frank and Roy had undertaken an excursion of discovery. They had just learned at school that every living thing has enemies and that everywhere amongst plants and animals there is a constant struggle for space and for food. Their teacher had suggested that they might find evidence of this struggle by making first-hand observations in their own garden.

"I've never seen any enemies attacking plants in our garden," said Roy.

"Neither have I," said Frank. "But let's see what we can find, anyway."

As they crossed the lawn, Roy stepped on a big dandelion plant without noticing it.

"Wait," said Frank, "let's examine this plant."

"It's just a harmless dandelion," remarked Roy.

But when they lifted the big leaves of the dandelion, they found that the grass underneath them had died. When further investigation showed that this was usually the case, the boys concluded that dandelions smother the grass.

"So it is an enemy of the grass, after all," admitted Roy.

Insect pests, weeds, and plant diseases must be kept in check in order to achieve a beautiful garden like the one pictured here. Constant vigilance must be exercised in all parts of the garden.

In the garden Frank and Roy found many other plant enemies. Pigweeds and mustards were sucking moisture and food from the soil around the carrots and parsnips and stealing their sunshine. And a patch of Frenchweed was coming up so thickly that, if it were left undisturbed, it would completely crowd out the slower growing asters.

But weeds were not the only enemies the boys found. In the cabbage patch they observed many leaves full of holes. On close examination they discovered many small green worms feeding on the leaves.

"The teacher was right, wasn't she?" said Frank.

"Oh, I don't know," Roy replied. "These are all little plants. Those big maples and the Virginia creeper that covers the porch are too big to have dangerous enemies."

"That's where you're wrong," said Frank. "See how many of the leaves of this maple tree have turned brown."

When they observed the trees closely, the boys found that whole colonies of plant lice or aphids were sucking the juice from the leaves. In other parts of the garden they found other plants suffering from a blight or plant disease.

The potato plant in the centre is healthy; the one on the left is affected with a disease called mosaic, the one on the right with leaf roll. A good gardener watches his potato patch for signs of disease. Diseased plants should be pulled up and burned. (Dept. of Agriculture photo)

On their tour of the garden, the boys made many interesting discoveries, which opened a new field of thought to them. When they seek further, they will find that each plant enemy itself has enemies. The green plant lice that feed on the maple, for example, are devoured by the ladybird beetle.

The plants we like to grow—domestic plants—are often less hardy than their enemies and could not thrive without our aid. So we check weeds, poison worms and bugs, and spray blights to prevent them from destroying what we want to grow. Which enemies are most dangerous to crops, and how they can be controlled, you will discover in this chapter.

1. PLANT DISEASES

TREATING SEED TO PREVENT PLANTS FROM BECOMING "SICK"

Plant diseases damage our crops to the extent of many millions of dollars every year. In every part of Canada, plant "doctors," or plant pathologists as they are called, are studying diseases of plants to learn more effective methods of controlling them. In other countries, also, a great deal of money and time is being spent in an effort to prevent this waste. In a campaign of this kind we can all help if we are able to recognize the symptoms of the more common plant diseases and know how to prevent or control them.

Most plant diseases are contagious and are spread from plant to plant by *spores,* just as diseases that attack you and

Slight Rust Injury Medium Rust Injury Severe Rust Injury

This illustration shows clearly how a plant disease may reduce crop yields. Compare the amount of grain in the three glasses.

me are carried from person to person by germs. The spores, which are extremely tiny, may be blown from one plant to another by the wind; they may be spread through the soil; or they may attack the seed and infect the young plants that grow from the seed.

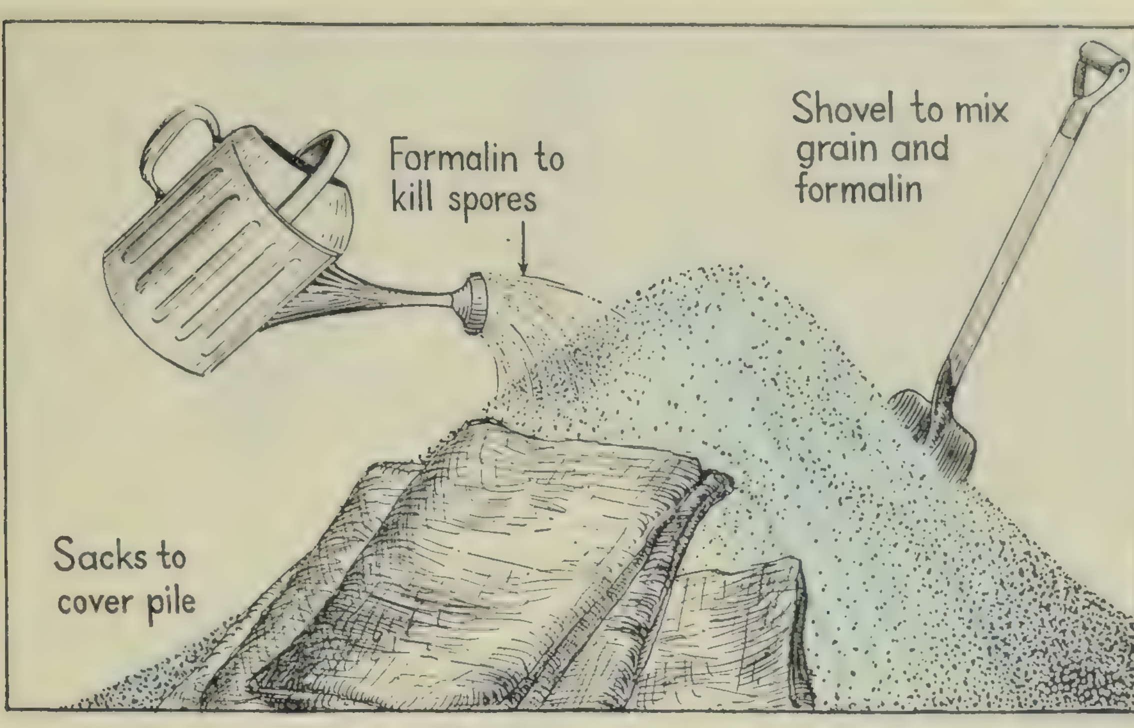
Plant diseases are caused by very, very small plants that belong to the group of plants called *fungi* (fŭn′jī—singular, *fungus*). Fungi contain no chlorophyll or leaf green and therefore are unable to make their own food, as green plants do. Mould, like that which you have probably seen growing on moist bread, orange or lemon skins, etc., is a common fungus. You know that when you have a cold in your throat, bacteria are growing there. When wheat is infected with rust, we know that a fungus has begun to grow in the wheat stems; and when a disease called *wilt* appears in flax, we know that bacteria have begun to grow in the flax plants.

The smuts of wheat: (*a*) a sound head; (*b*) a head badly infected and (*c*) a head partially infected with bunt or stinking smut; (*d*) and (*e*) heads infected with loose smut. (Dept. of Agriculture photo)

Sometimes water and milk are not safe to drink until they have been treated to kill disease germs in them. Neither is some seed safe to plant until it has been given treatment to destroy disease spores it may be carrying. The usual method of treating seed is to apply a chemical that will kill the spores without harming the seed. Many farmers make a practice of treating their seed grain every spring before sowing it.

COVERED SMUT OF WHEAT

Covered smut, or as it is also called, bunt or stinking smut, affects the seeds of wheat. During the summer, while the crop is growing, the smut fungus develops within the wheat plants. Later, the kernels, instead of filling out as they should, develop into spore packages called *bunt balls,* which are filled with several millions of tiny spores. At threshing time, the threshing machine breaks the bunt balls, and the spores are scattered. They become lodged in the woolly



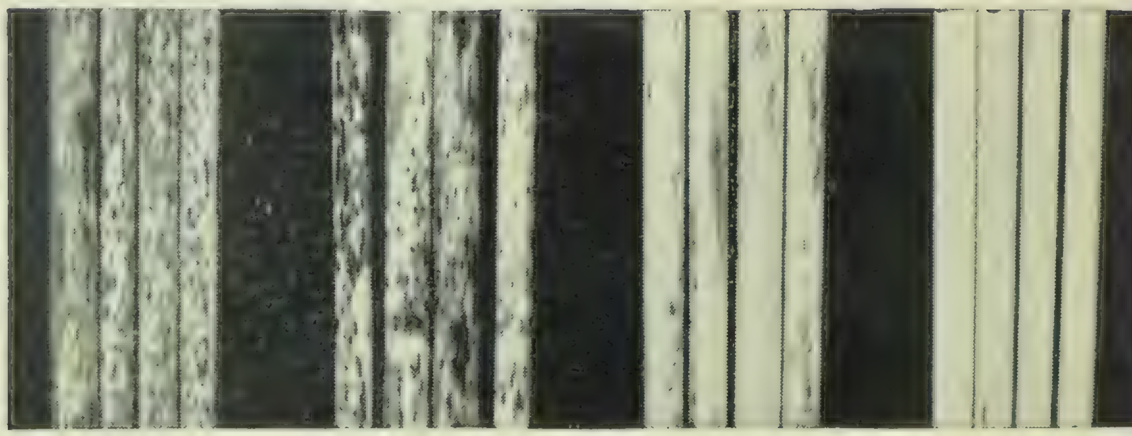
Treating grain with formalin to kill the spores of covered smut. The seed should be treated the night before it is sown. The wheat should be piled on the floor of the granary or in a wagon box and thoroughly sprinkled with formalin solution (one pint of formalin to forty gallons of water). The pile should be well shovelled back and forth to ensure the moistening of every kernel. The seed should then be covered for two hours, after which it should be spread out to dry. Other methods may be used to treat the seed for covered smut. If you know about them, tell your class.

ends and the creases of healthy kernels. There they remain inactive during the winter. The following spring, when the seed is sown, the spores germinate and infect the new wheat plants.

Covered smut of wheat may be controlled by killing the spores on the wheat kernels with formalin, bluestone, ceresan dust, or copper carbonate. Formalin is probably most commonly used.

Oats and barley are also affected by this type of smut. Before being sown, all seed wheat, oats, and barley should be treated. Many bunt balls can be blown out of the seed by a fanning mill; this is an important reason for cleaning seed well.

Another kind of smut (loose smut) lives inside the seed and is much more difficult to deal with.



On the left, stems of susceptible varieties of wheat covered with rust pustules; on the right, stems of rust-resistant varieties. Find out what rust-resistant varieties of wheat are grown in your district. (Dept. of Agriculture photo)

Other diseases, such as rust, take-all, etc., also affect grains, but these cannot be controlled by seed treatment, because they do not infect the seed.

COMMON SCAB OF POTATOES

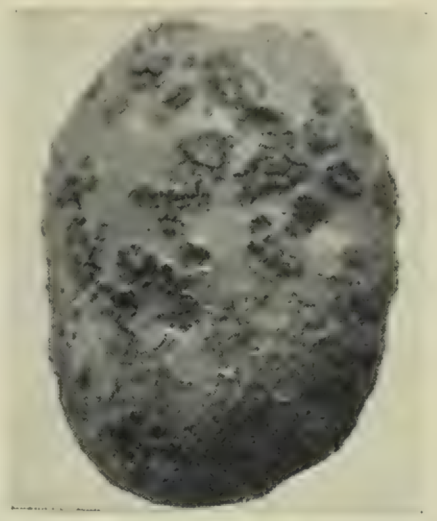
Common scab is a very prevalent potato disease. It causes the skins of the potatoes to become rough and very unsightly. It does not reduce the yield of the crop to any great extent, but it results in heavy losses because scabby potatoes are not very saleable. The disease lives in the soil and is spread by planting scabby potatoes.

Common scab may be controlled by soaking seed potatoes in a solution of corrosive sublimate or formalin.

OTHER PLANT DISEASES

Most of our crops—grain, fruit, vegetable, and even some of our ornamental plants—may become infected with diseases. Many different methods are used to prevent and control the various diseases. In some cases, the seed is treated, as described on page 221. In others, the plants are sprayed with chemicals to kill spores on their leaves. In still others, diseased plants are rogued, or pulled up, and destroyed. In cases where the disease lives in the soil, crop rotations are

frequently planned, so that the same kind of crop may not be grown too often in the same soil.



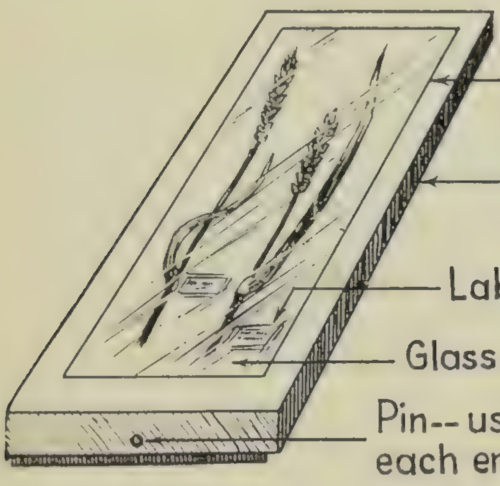
Common scab on a potato tuber. Watch for signs of scab in your own patch.

Something to Do

1. Make a collection of plant disease specimens. Include, if you can, rust of wheat and other grains, loose and covered smut of various grains, ergot on rye, other diseases of grains such as root rot, common scab of potatoes (dry and press a thin slice of scabby potato peeling), etc. Your collection may be mounted and preserved in the manner illustrated in the diagram below.

2. Watch newspapers and farm magazines for accounts of the work being done with plant diseases, especially rust and other diseases of grains. Although much has already been accomplished, further progress will no doubt be made in the near future in developing disease-resistant crops by careful selection and cross-breeding.

3. Write to the Publications Branch, Department of Agriculture, Ottawa, for some good bulletins dealing with plant diseases. Several of these bulletins may be obtained free of charge.



A good method of mounting plants and insects. Use waste pieces of glass and boxes. Check your information carefully before printing your labels.

NOTE.—Only one copy of each bulletin should be ordered for any one school. All bulletins should be preserved and used for reference purposes. They should not be cut up and pasted in scrapbooks.

Review Questions and Exercises

1. What kinds of enemies attack plants? What enemies did Frank and Roy find in their garden?
2. What are fungi?
3. How are contagious diseases spread?
4. How may seed wheat be treated to prevent the crop from being infected by covered smut?
5. What treatment is used to prevent common scab in potatoes?
6. What causes diseases of plants? How are these diseases spread?

2. INSECT PESTS

Insect pests are at work everywhere. To control them is a gigantic undertaking. Many insects are our friends, but an enormous number are very injurious. In Canada, the average yearly loss from insects is $175,000,000. It has been estimated that in this country alone insects annually destroy the work of 100,000 able-bodied men.

Something to Do

Even harmful insects are interesting. Make a study of one insect that damages our crops. (1) Send to the Extension Department, University of Saskatchewan, Saskatoon, for bulletins about the insect. (2) Watch magazines and newspapers for information about it. (3) Collect and preserve specimens of the various stages of its life-history. (4) Draw sketches to illustrate its habits and life. (5) Learn how to control it.

CUTWORMS CUT CROP YIELDS.

Cutworms are a constant menace to the production of practically all crops of field and garden. Their control is one

of the farmers' greatest problems. Cutworms are caterpillars. The insects in the adult form are night-flying moths, commonly called millers. There are many kinds of cutworms. The two most common and most harmful are the red-backed and the pale western.

Moths of the red-backed cutworm: left, at rest; right, with wings spread; natural size. (After Gibson)

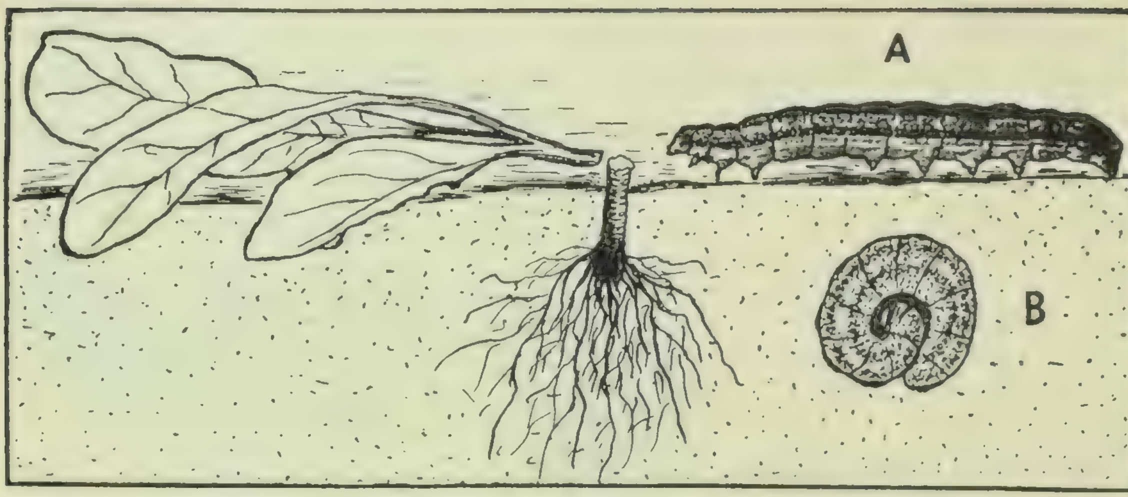
THE RED-BACKED CUTWORM

The adults of the red-backed cutworm are medium-sized, grayish brown moths with a few white marks and dark coloured areas on their front wings. They are common in late July and August. During the day the moths hide away, but at night they become active, feeding on the nectar of flowers and laying eggs.

The eggs, which are very small, are laid in fine, loose, dry soil during the late summer. They hatch during the first lengthy warm spell in the following spring.

From the eggs hatch tiny larvae or caterpillars. These are the cutworms. They are dark gray in colour, with two broad bands of red along their backs. When full-grown, a cutworm is about as thick as an ordinary lead pencil and about one and three-eighths inches long. When it is disturbed, it rolls up into a ring. Cutworms remain below the ground during the day, but come above the surface of the ground at night to feed. The harm they cause is very great. Sometimes they merely cut the plants off at or near the surface of the soil. At other times they eat the leaves as well. Usually they can be found by digging into the loose soil near the plants they have damaged during the night. Cutworms are full-grown and cease feeding about the end of June.

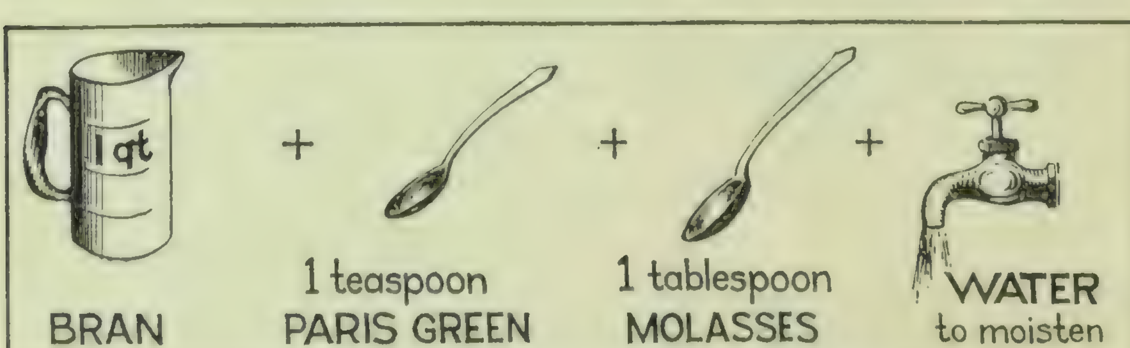
A full-grown red-backed cutworm, natural size. (After Strickland)



A, a cutworm destroying plants at night. B, a cutworm coiled up and inactive in the soil during the day. Have you ever found them thus?

They then build a small, oval, earthen cell one or two inches below the surface of the soil. In this cell they pass the pupa stage, remaining inactive while they change from cutworms to moths. The pupae are dark reddish brown in colour. They may often be found in garden soil. After about three or four weeks, the adult moth emerges.

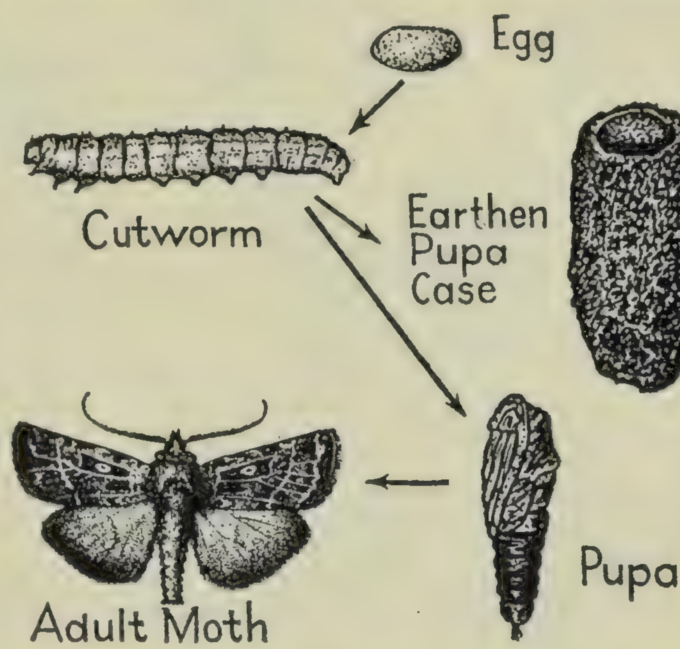
Fully one-half of the damage done to field crops and ninety per cent of the damage done to garden crops by cutworms may be prevented by keeping the insects in check. This may be done by the following methods: (1) Protecting insect-eating birds, which are natural enemies of the cutworms. (2) Using poison baits. This is the most effective method. It consists in spreading poisoned materials in the fields and gardens to attract and destroy the cutworms. (3) Refraining from



Poison bait for cutworms—garden quantity.

cultivating, from August 1st to September 5th, soil where cutworms are numerous. This allows a crust to form on the surface and prevents the moths from laying eggs in the soil. (4) In the garden, digging down into the soil and locating and destroying the cutworms. (5) Placing a cylinder of tin or of heavy brown paper around individual plants in the garden as they are set out.

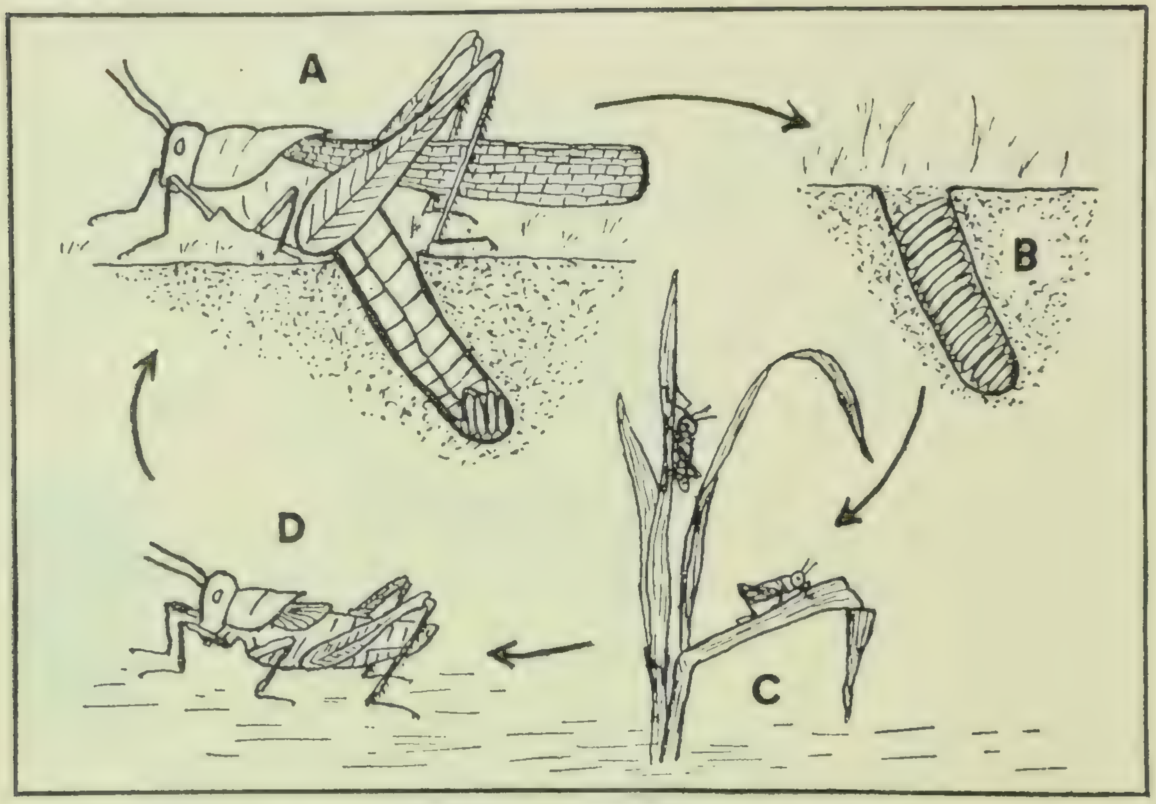
THE PALE WESTERN CUTWORM



The life-history of the pale western cutworm.

The pale western cutworm is readily distinguished from the red-backed. It is a pale slate gray with a yellowish head, on the front of which are two distinct, short black marks. The life-history of this cutworm is similar to that of the red-backed. The moths are numerous during the last three weeks of August and the first week of September. Watch for them in the early fall.

The pale western cutworm feeds about one inch below the surface of the ground. Consequently poison bait is not an effective method of control. In fact, once these cutworms are discovered in a crop, little can be done to save it. The following methods of control are recommended: (1) Leaving the land without cultivation of any kind from the first of August to the middle of September. (2) Starving young cutworms in fields to be seeded. This may be done by destroying all green growth two weeks before the crop is to be sown. With no plants to feed upon, the young cutworms die.



The life-history of the grasshopper: A, the female adult depositing eggs in the late summer. B, an egg pocket containing white, oval-shaped eggs. C, young nymphs that hatch from the eggs; they have no wings. D, a nymph several weeks old; its wings are beginning to develop.

GRASSHOPPERS

Grasshoppers are controlled chiefly by (1) the use of poison baits, and (2) deep fall ploughing to bury the eggs. Various mixtures are used as baits. The most common one is composed of bran or sawdust, arsenic, salt, and water. It is spread thinly on the ground during warm, sunny days when the hoppers are actively feeding.

Something to Do

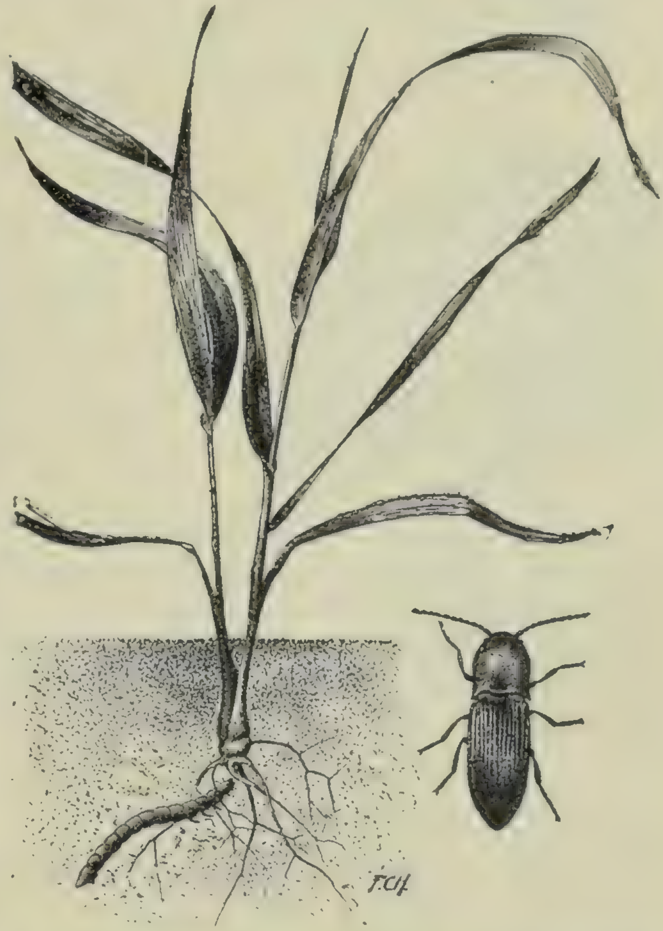
1. Look for cutworms in the spring. Bring specimens of the various kinds to school to show your classmates. Feed them with fresh leaves of garden crops. Observe their habits and the way in which they develop.

2. Look for cutworm pupa cases when you are ploughing or working in the garden in the early summer. Place some cases

in a box in a moderately warm place, and watch for the moths to emerge. As the moths usually emerge during the summer, keep the cases at home in order to observe the moths when they appear.

WIREWORMS

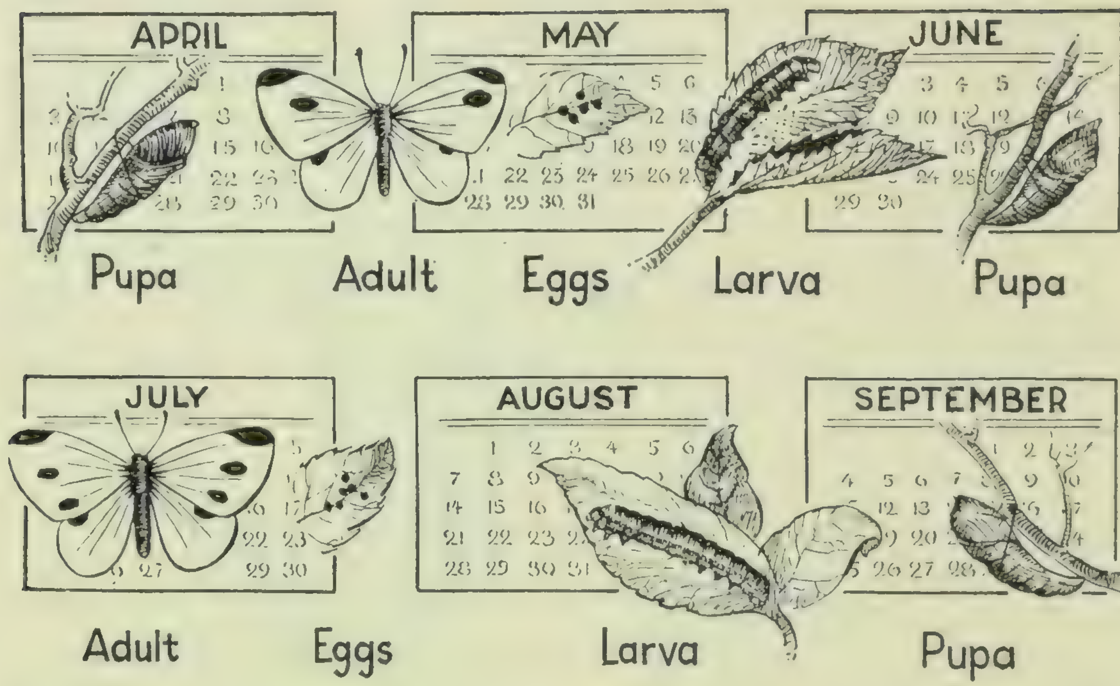
Losses resulting from the work of wireworms are sometimes very great. The worms attack potato tubers, bulbs of onions, roots of garden grass, and grain crops. In the spring they burrow into newly seeded grain and prevent it from germinating.



A wheat wireworm feeding upon the roots of a wheat plant, and the adult, which is a click beetle. (After Hudson)

Adult wireworms are beetles about half an inch long and brown or black in colour. They are commonly known as *click* beetles, because when placed on their backs they spring into the air with an easily heard click. Although they have fully developed wings, they do not fly, but live on the ground, feeding greedily on plant growth. Fortunately they do little or no damage.

About June the female click beetles burrow into soil, preferably covered evenly with plant growth, and lay their eggs about five inches below the surface. The eggs hatch in about a month's time into slender orange-yellow larvae, which when full-grown are about an inch long. The larvae are called *wireworms* because their bodies are hard, shell-like, and shiny. They live entirely underground, feeding on decaying



The life-history of the cabbage butterfly. The adults are medium sized, yellowish white butterflies with black markings as illustrated. The calendar pages tell you the time of year in which the various stages of this very destructive insect occur. It winters in the pupa stage. The eggs and larvae are found on the leaves of cabbages. The larvae are destroyed by spraying Paris green on the leaves.

vegetable material and on the roots of growing plants. The wireworm larvae grow very slowly and spend from two to four years or more beneath the soil, never coming to the surface. When full-grown, the wireworm changes into a pupa. This is the resting stage and is passed in a small earthen cell a few inches below the surface of the soil. The adult beetle emerges from the pupa case in the autumn but remains in the soil until the following spring.

It is difficult to control wireworms because of their habit of remaining underground, but certain practices have been found helpful. The use of chemical fertilizers often encourages crops to make rapid growth and outgrow wireworm damage. Crop rotations may reduce the damage considerably, since alfalfa, clover, oats, fall rye, and barley are not so severely attacked as other crops. Summerfallowing, com-

mencing early in June, with frequent cultivation to keep down all weed growth, starves the wireworms in the soil. Cultivation also exposes the insects to birds, which destroy large numbers of them. In gardens, a poison bait, such as a bunch of clover or a slice of potato, poisoned with Paris green and placed under a board, may poison many beetles. Pieces of potatoes or lumps of dough placed in the soil attract wireworms. The baits may then be dug up and the insects in them destroyed.

Parts of a potato plant badly infested with one of its worst enemies—the Colorado potato beetle. A, eggs on the under side of the leaf; B, larvae devouring the leaves; C, pupa; D, the adult beetle.

THE COLORADO POTATO BEETLE OR POTATO BUG

Both the adult and the larva of the Colorado potato beetle feed ravenously upon the leaves of potato plants. They may completely destroy the leaves of an entire patch unless they are checked as soon as they are discovered. The adults, which are not bugs but beetles, pass the winter in the ground. In the early spring they emerge, and the females lay their orange coloured eggs on the leaves of early young potato plants. The eggs hatch in a week or ten days. The larvae are full-grown in two weeks, after which they bury themselves in the ground to pass the pupa stage. In about two weeks more, the adult beetles emerge from the pupa cases. They at once lay more eggs for a second family, which by fall will have reached the adult stage.

Control of potato beetles is accomplished by the use of poison sprays such as Paris green or arsenate of lead. These poisons are sprayed on the leaves of the potato plants and thus destroy both larvae and adult beetles.

Plant lice on the leaves and stems of a rose. (After Hudson, Entomological Branch, Dept. of Agriculture)

SAP-SUCKING INSECTS

Many insects, like the cutworm, the wireworm, the grasshopper, and the potato beetle, are equipped with biting mouth-parts. Others have mouth-parts fitted for piercing and sucking. Insects in the latter class bore into plants and suck the sap. *Aphids* or *plant lice* are common examples of injurious sucking insects.

Something to Do

Find some aphids. They are common on house plants, currant bushes, Manitoba maple trees, and other plants. They are quite small and are usually green in colour. Bring a branch or plants infested with aphids to school to show your classmates. Observe them for a short time, then be sure to destroy them. Use a magnifying glass for your observations. You will probably find some of these insects with their tube-like mouth-parts plunged deep into the plant, apparently sucking sap greedily. You may see some that have wings; others will be wingless.

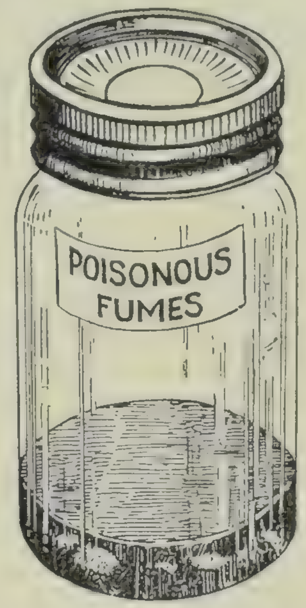
Aphids produce a sweetish liquid or honey dew. They are often so numerous on Manitoba maple trees that the liquid falls from the leaves in a sticky shower. Sometimes ants keep aphids in ant-hills to supply them with honey dew. Aphids may be useful to ants, but man regards them as wholly harmful, since they destroy many useful plants that he wishes to grow.

Since aphids do not eat the plant, placing poison on the leaves will not destroy them. They must be controlled by sprays that clog up their breathing pores or that contain

poisons which affect their bodies. Soapy or oily solutions are good. A useful soap solution may be prepared by adding one pound of whale oil soap to from four to six gallons of soft water. Certain sprays, such as Black Leaf 40, which may be purchased from florists, are also effective in destroying aphids.

Useful Insect Bulletins

The following useful publications may be obtained from the Director of Publicity, Department of Agriculture, Ottawa: *The Beet Webworm; The Red-backed Cutworm and its Control in the Prairie Provinces; Household Insects and their Control; Vegetable Insects and their Control; Injurious Shade Tree Insects of the Canadian Prairies; Insects of the Flower Garden and their Control; Aphids or Plant Lice; The Western Wheat-Stem Saw-fly and its Control.* All are well illustrated.



An insect-killing bottle. If you make a collection of insects, you should kill them in the proper way. Perhaps your druggist will help you to prepare an insect-killing bottle. Learn to use it correctly.

Something to Do

Find information in newspapers and magazines about new insect-killing chemicals, such as D.D.T., and the new "bug bomb." Keep up to date, also, in regard to insect-resistant crops, such as Rescue wheat, which resists saw-fly attacks.

Review Questions and Exercises

1. Name the two most harmful and common kinds of cutworms found in Saskatchewan. How can the larva of each be identified?

2. Outline the life-history of the cutworm, mentioning egg, larva, pupa, and adult stages. In which stage is the insect harmful?

3. Discuss the problem of the control of cutworms under the following headings: (*a*) by methods of cultivation, (*b*) by poison

From the time the tree is planted until the fruit matures, a fruit-grower must make constant use of the findings of scientists if he wishes to harvest luscious fruit like that shown here. Make a list of some ways in which science should be applied in growing apples and other kinds of fruit. (Canadian Industries, Ltd. photo)

baits, (*c*) in gardens. Which of the methods you suggest are effective against the red-backed cutworm and which against the pale western?

4. Name one other insect that is injurious to our crops. Outline its life-history. In what stage or stages is it harmful? How can it be controlled?

5. How are sucking insects controlled? Why are poison baits of no value in checking these insects?

6. Organize committees to make a survey of the damage that harmful insects are causing in gardens or grain fields in your community. Find what control methods are being used to keep the insects in check.

3. WEED PESTS

Weeds are plants growing in the wrong place—plants that we do not want, but that sometimes continue to grow in spite of all we can do to get rid of them. They present to farmers and gardeners one of their greatest problems. If weeds are not held in check, fine crops cannot be grown; farms cannot be operated profitably; nor can shrubs, flowers, and lawns be produced to beautify our homes.

HOW MUCH DO WEEDS COST US?

Weeds are *thieves*. They decrease yields by robbing the soil of plant food materials and moisture that was not meant for them. There is no moisture to spare for weeds in the grain-growing areas of Western Canada. Weeds are *usurpers*. They crowd out useful but less hardy plants and deprive them of the light they need. Weeds are *destroyers*. They lower the

grade and increase the dockage in grain crops. Burs reduce the value of wool. Frenchweed or stinkweed spoils the flavour of milk. Weeds of any kind detract greatly from the value of a farm. Weeds are *wasteful* and *expensive*. It costs money and requires labour to get rid of them. When weeds infest a crop, the cost of harvesting and threshing is greatly increased. Furthermore, it is estimated that over $500,000 is spent annually for freight on weed seeds shipped in wheat and other grains from farms in Saskatchewan to the terminal elevators at Fort William and Vancouver. In Canada, the losses resulting from weeds amount to millions of dollars a year. The annual loss in one province alone has been set at over $60,000,000. This is a tremendous price for us to pay for the useless, wasteful weeds that grow in our fields.

NOXIOUS WEEDS

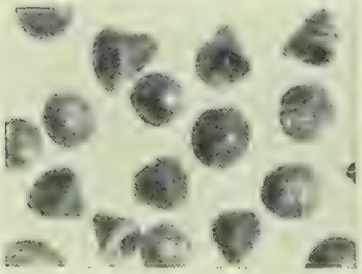
Certain weeds, known as *noxious* (nŏk′shŭs) weeds, cause so much damage to our crops that they have been named specially in the *Noxious Weeds Act*. The noxious weeds of Saskatchewan are:

perennial sow thistle	wild mustard	Russian thistle
annual sow thistle	stinkweed	blue bur
Canada thistle	tumbling mustard	ragweed
couch grass	hare's ear mustard	purple cockle
poverty weed	ball mustard	cow cockle
wild oats	false flax	night-flowering catchfly
darnel	bird rape	bladder campion
barberry (except Japanese barberry)		

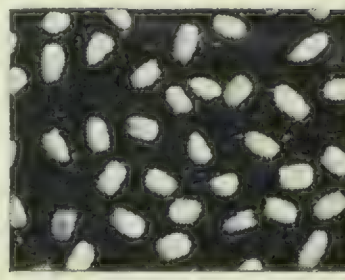
Everyone who wishes to grow crops should be familiar with these weeds and with the methods of controlling them.

CLASSES OF WEEDS

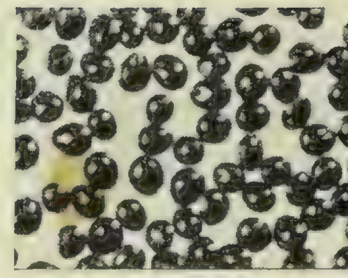
Weeds are classified according to their length of life. *Annuals* grow, flower, and produce seed, and die in one year. They are reproduced from seed. *Winter annuals* are annual weeds that begin to grow in the fall and survive the winter.



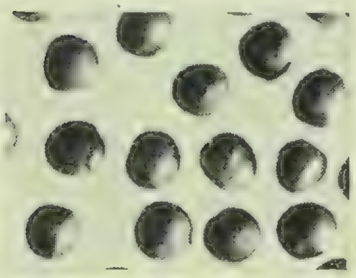
Russian Thistle



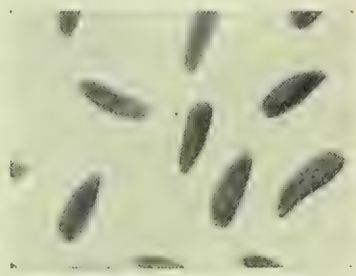
Tumbling Mustard



Pigweed

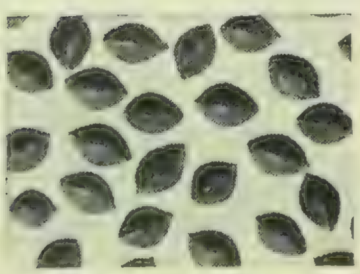


Cow Cockle

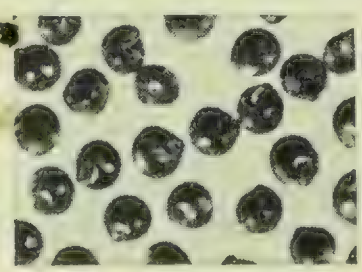


Perennial Sow Thistle

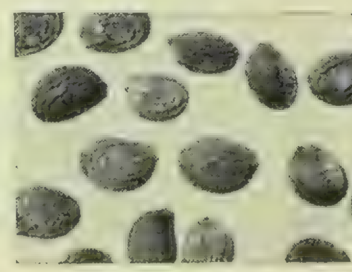
Wild Mustard



Wild Buckwheat

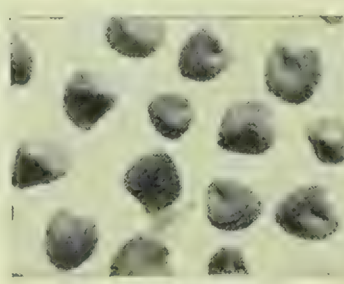


Lamb's Quarters



Stinkweed

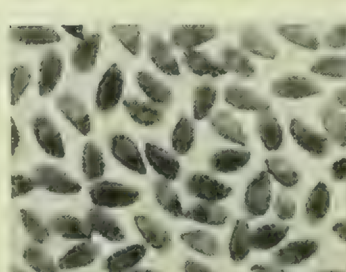
Canada Thistle



Corn Cockle

Wild Oats

Poverty Weed



Russian Pigweed

Great Ragweed

WEED SEEDS COMMONLY FOUND IN WESTERN CANADA

Such weeds, you will readily see, have a great advantage over the crops that are not planted until the following spring. *Biennials* are two-year plants. They store up food, usually in the root, the first year. The second season they produce seed. *Perennials* live for more than two years.

HOW TO KNOW WEEDS

The only way to learn to recognize weeds is to study the weeds themselves. A very good method to use is to learn their general characteristics by families. The members of each family have many distinguishing marks in common, and once the identity of an unknown weed has been traced to the proper family, complete identification is much easier. The descriptions given here will be useful for reference.

Something to Do

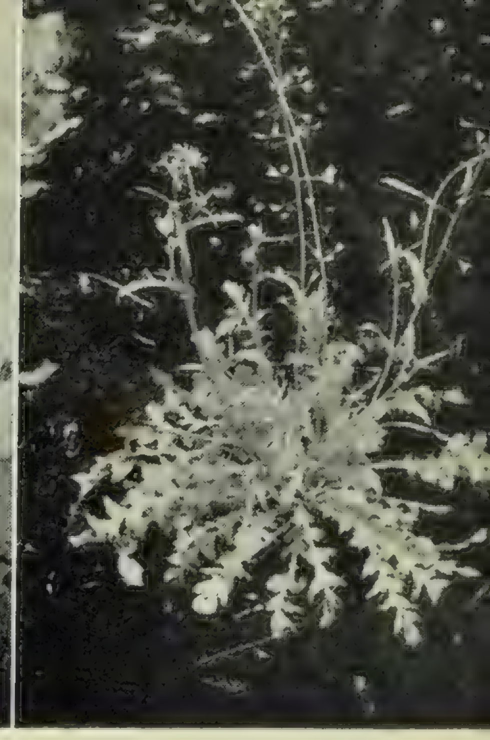
The following plant families include most of the noxious weeds of Saskatchewan. Select two that include weeds common in your locality, and make a special study of them. In each case, collect a good specimen of the weed described and a few others in the same family. Compare your first specimen with the description. Examine the other weeds to find their common characteristics and other facts about them.

1. THE MUSTARD OR CRESS FAMILY.—All the plants in this family have cross-shaped flowers with four petals. Seeds are produced in pods.

Frenchweed or *Stinkweed.*—Annual or winter annual, reproduced by seeds. Root—fibrous. Stem—erect, smooth, branching, from two to twenty-four inches high. Leaf—wavy edge; upper leaves stalkless and clasp stem with arrow-shaped base; lower leaves have stalk. Flower—small, white, four petals, in clusters that bloom and produce seed from early spring to late fall. Seed—small, purple with a metallic appearance, ringed, borne in pods that are winged with a notch at the top.

All the photographic illustrations of weeds in this chapter were reproduced through the courtesy of the Agricultural Department of The North-West Line Elevators Association.





WILD MUSTARD HARE'S EAR MUSTARD SHEPHERD'S PURSE

Other weeds of the Mustard family.—Wild mustard, tumbling mustard, hare's ear mustard, ball mustard, green tansy mustard, pepper grass, shepherd's purse, bird rape, false flax.

2. THE THISTLE OR DAISY FAMILY.—The flowers are produced in heads or compact clusters. The head of a sunflower or a thistle is a good example. Each part of the head is a little flower or floret. Many seeds have feathery parachutes.

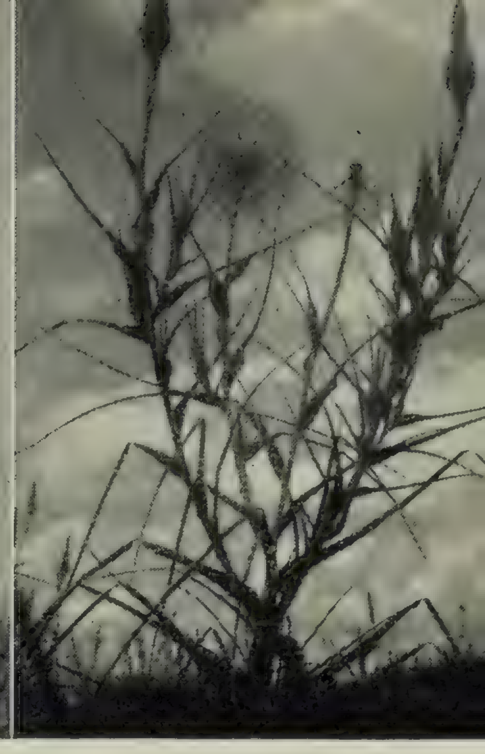
Perennial sow thistle.—Perennial, reproduced by seeds and running underground stems or rootstocks; rootstocks have been found with six plants on a two-inch length, others have measured eighteen feet. Stem—from one to five feet tall, hollow, filled with bitter milky juice, branching at top. Leaf—long, deeply cut, with points turning slightly backwards, filled with bitter milky juice; clasps stem with arrow-shaped base. Flower—large, bright yellow, composed of florets, in large clusters of a dozen or more flowers. Seed—small, dark reddish brown, deeply ribbed lengthwise and cross-wrinkled, topped with a parachute of fine silky hairs. You should be able to identify perennial sow thistle.

Other weeds of the Thistle family.—Canada thistle, annual sow thistle, dandelion, ragweeds.

3. THE GRASS FAMILY.—These plants have long, narrow leaves and jointed stems. Good examples are grains and common grasses.

Wild oats.—Annual, reproduced by seeds. Root, stem, and leaf closely resemble cultivated oats. Seeds—more slender than





PERENNIAL SOW THISTLE GREAT RAGWEED GOAT'S BEARD

cultivated oats, white, black, gray, and brown; have horseshoe-shaped mouth at base, which is surrounded by stiff bristles, and a twisted awn bent at right angles.

Other weeds of the Grass family.—Quack grass, sweet grass, darnel, foxtail.

4. THE PIGWEED FAMILY.—These plants have small greenish, inconspicuous flowers and seeds wrapped in papery covers.

Russian thistle.—Not a thistle. Annual, reproduced by seeds. Root—small, tap, easily broken off when ripe in the fall. Stem—branching, dark green when young, striped with red as it ripens. Leaf—long, needle-shaped, pointed; drops off soon after seed is produced. Flowers—small, greenish, inconspicuous; borne singly just where leaf is attached to stem. Seed—small, fifty thousand to a plant, olive green, cone-shaped, coiled like a snail shell; papery covering. A very bad tumble weed.

Other weeds of the Pigweed family.—Lamb's quarters and Russian pigweed. Red-root pigweed does not belong to this family, but to one closely related.

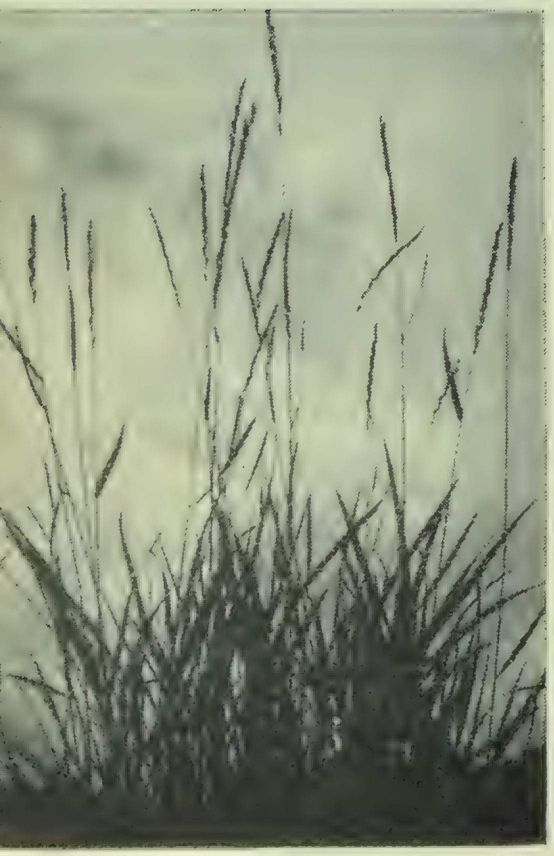
5. THE PINK FAMILY.—The stems of the plants are usually swollen at the joints. The parts of the flowers are usually in fives, occasionally in fours. Petals are sometimes missing. The seeds are in one- to five-celled pods and attached to a column that rises from the centre of the flower.

The purple cockle.—Annual and winter annual. Root—fibrous. Stem—erect, from two to three feet tall; has few

branches. Leaves—long, narrow, pointed; whole plant covered with fine silky hairs. Flowers—large, purple, borne singly at tips of branches. Seeds—large, black, rounded triangular in shape, rough; in large pods with five teeth at top.

Other weeds of the Pink family.—Cow cockle, night-flowering catchfly, bladder campion.

Note to the Teacher.—A practical test on weeds will be found interesting and helpful. Have on hand specimens of the plants and seeds of common weeds. Ask pupils to identify them. Make it a game or contest. Do not let it become a burden. Pupils do well to learn to recognize eight or ten weeds in a year.


COUCH GRASS

Review Questions and Exercises

1. What is a noxious weed?
2. Name ten noxious weeds common in your district.
3. Gather specimens of all the noxious weeds you can find in and about your schoolyard. Group them in their respective plant families.
4. Describe the injurious effects of weeds.
5. Mention two distinguishing characteristics of two plant families you have studied.

Something to Do

1. Make a study of the weeds common in your locality. Collect a representative specimen of each weed, and press and mount it. Classify the weeds in your collection as annuals, winter annuals, biennials, and perennials.

2. Make a collection of weed seeds. Place the seeds in small bottles, and mount the bottles on cardboard. The names of the seeds may be pasted on the bottles or printed on the cardboard below each bottle.

3. Try to recognize the weeds you have studied when you see them in fields and gardens or along the roadside.

LAMB'S QUARTERS — RED-ROOT PIGWEED — PURPLE COCKLE

4. Arrange a field trip for the purpose of studying weeds. Try to enlist the assistance of someone who is familiar with a number of common weeds.

5. Make a study of the ways in which weeds are scattered. Prepare a chart to illustrate these methods.

6. Draw charts to show the damage caused by weeds.

7. Plant a number of seeds of different noxious weeds in a box or in a plot outside. Watch for the young plants, and learn to recognize them in their earliest stages.

Useful Weed Books

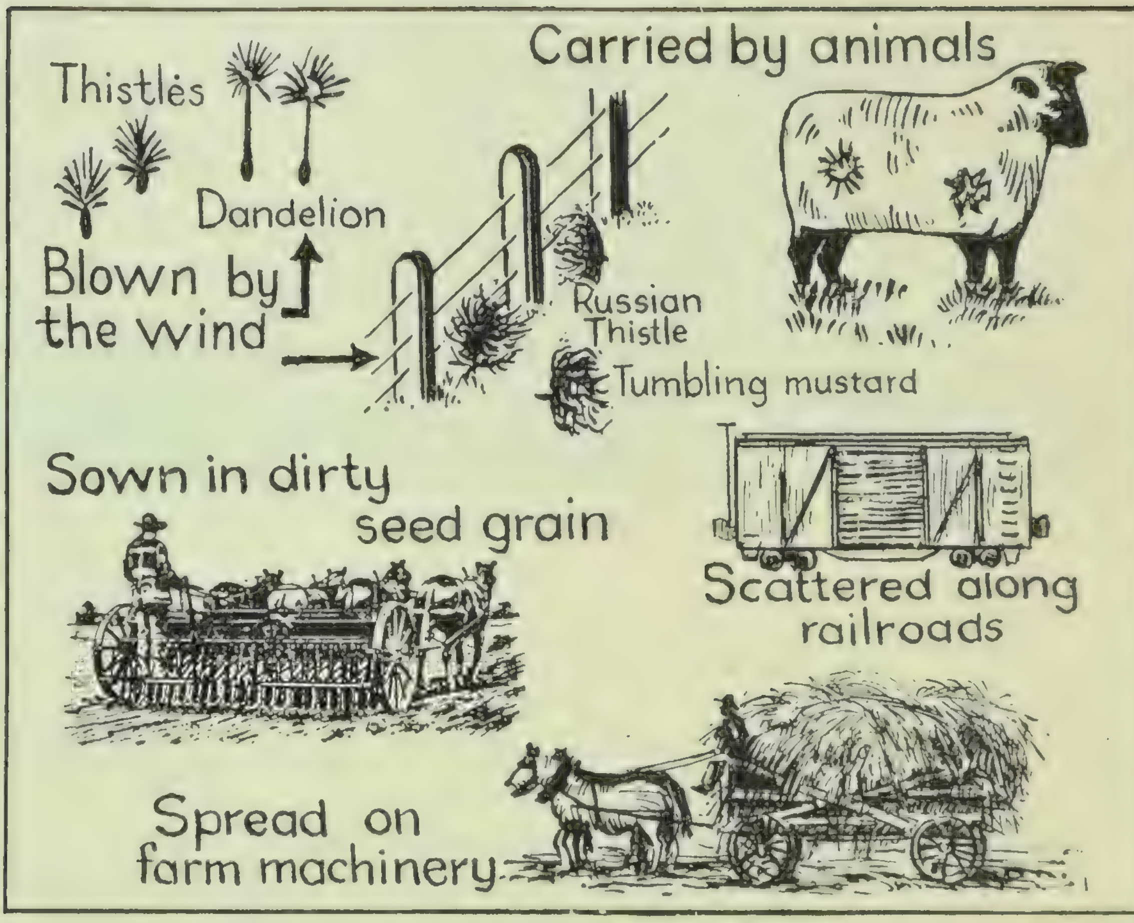
1. *Weeds, Their Identification and Control,* Field Crops Branch, Department of Agriculture, Regina. Free.

2. Nine coloured illustrations of weeds on cards. One set will be sent free to each school by the Field Crops Branch, Regina.

3. *Weeds and Weed Seeds,* Bulletin No. 4, N.S., Publications Branch, Department of Agriculture, Ottawa. Free.

4. *Farm Weeds in Canada.* Every school should purchase a copy of this excellent book, which is beautifully illustrated in colour. Send to the Office of the King's Printer, Government Printing Bureau, Ottawa, for a copy. Price $2.00.

5. *An Illustrated Guide to Prairie Weeds* by K. W. Neatby. This is a 72-page booklet with a large number of illustrations. Every school should have a copy. Price 25 cents. Published by The North-West Line Elevators Association, Winnipeg, Manitoba.



Some ways in which weeds are scattered. Do you know other ways?

HOW SHALL WE FIGHT WEEDS?

In the war against weeds, an ounce of prevention is worth infinitely more than a pound of cure. To stop the spread of these harmful plants, a number of precautions should be taken. (1) Stook wagons, threshing machines, and other farm machinery should be well cleaned before being moved from one place to another. (2) Weeds along roadsides and fences should be prevented from producing seeds to get into surrounding fields. (3) Only well-cleaned seed should be sown. Some farmers actually sow quantities of noxious weed seeds with the seeds of their grain crops. Is this a good practice? If grain cannot be properly cleaned for seed, it should be sold, and seed free from weeds should be purchased in its place. (4) Manure containing weed seeds should not be spread on fields until it

is well rotted. When manure is thoroughly rotted, the germinating power of weed seeds in it is destroyed.

The prevention and the control of weeds are a community concern. One person can do little by himself. How can your neighbour keep his fields free from weeds if your fields are full of weeds producing seeds to spread far and wide? How can one person have a clean lawn, if the lawn next door or the vacant lot across the street is infested with dandelions or other weeds? Only by the co-operation of every person in the locality can weeds be successfully held in check. Are you doing everything you can do to prevent the spread of these wasteful plants?

ALL WEEDS CANNOT BE CONTROLLED BY THE SAME METHODS.

Annuals must be attacked in one way and perennials in another. Why?

Annuals are reproduced by seeds. The full-grown plants soon die, but the seeds may remain alive in the ground for many years. Therefore, if we wish to control annuals, we must do two things: (1) see that the seeds in the soil grow into plants at a time when it is possible to destroy them, and (2) prevent plants from producing more ripe seeds.

Perennials are reproduced by rootstocks or underground stems as well as by seeds, and the parent plants do not die in a year. In controlling perennials, therefore, it is the plants themselves and the rootstocks that we must attack and kill. Of course, if there are seeds of perennials in the soil, they must be made to germinate in order to destroy them.

HOW TO ATTACK ANNUALS

Remember that in dealing with annuals it is the seed that must be attacked. In choosing your method, keep in mind that: (1) Shallow cultivation in the fall will germinate the seeds that are in the soil. The plants thus started will be killed by the frost. (2) Early spring cultivation will destroy

early plants and germinate more seed. (3) Summerfallow, cultivating at intervals as necessary, will germinate seeds and destroy plants started by the previous cultivation before they can produce more seeds. (4) Sowing the land down to grass or sweet clover for a few years will keep weeds in check. (5) Live stock, particularly sheep, pastured on the summerfallow will help greatly to control weeds. (6) Using certain fertilizers will encourage the rapid growth of crops to keep them ahead of the weeds.

PLANTS THAT ARE REPRODUCED BY SEEDS PRODUCE GREAT QUANTITIES OF SEED

One Tumbling Mustard plant produces	1,000,000 seeds
One Lamb's Quarters plant produces	50,000 seeds
One Frenchweed plant produces	18,000 seeds
One Russian Thistle plant produces	50,000 seeds

Do not let these plants go to seed. Why?

METHODS OF CONTROLLING WINTER ANNUALS

Stinkweed and other winter annual weeds can be controlled by the same methods as annuals, with one addition. A second cultivation of the soil is necessary in the fall to kill plants started by the first cultivation. Remember, winter annuals are not killed by winter frosts, as other annuals are. Biennials may be controlled by similar methods.

HOW TO DEAL WITH PERENNIALS

Perennial sow thistle and Canada thistle are among our worst weeds. When they are present in a field, it means a fight to the finish. Keep in mind that in this case it is the plants that must be attacked. Why?

In dealing with perennials: (1) Black summerfallow, ploughing deeply enough to turn up the rootstocks early in June. Then cultivate the soil for the remainder of the summer,

allowing no thistle leaves to appear above the ground. This has the effect of both starving and smothering the plants. Why? (2) Plough deeply in the fall just as soon as the crop is harvested. Then cultivate the soil well until freeze-up. (3) Practise crop rotations; brome grass and sweet clover are good weed smotherers. Perennial sow thistle is never so troublesome where mixed farming and crop rotations are practised. (4) If your fields are badly infested with sow thistles, sow them with grass, and pasture sheep in them. Sheep relish sow thistles.

NOTE.—Bulletin No. 58, *Perennial Sow Thistle,* which may be obtained free from the Field Crops Branch, Regina, contains more detailed discussions about the control of this weed pest.

Guide to Farm Practice in Saskatchewan, a 100-page booklet containing valuable information regarding cereal crops, forage crops, cropping systems, weed control, insect pest control, horticulture, soils, agricultural engineering, live stock, poultry, and dairying, can be secured free of charge upon application to the Agricultural Extension Department, University of Saskatchewan, Saskatoon. It is revised and reprinted periodically. Every school should secure a copy of the latest edition.

THE NOXIOUS WEEDS ACT

Each province in Canada has its own Noxious Weeds Act.

The Noxious Weeds Act of Saskatchewan: (1) Lists the noxious weeds. (For the list, see page 235.) (2) States that "it shall be the duty of every owner or occupant of land to destroy noxious weeds thereon and to prevent the spread of weeds to other lands." (3) Sets forth the conditions respecting the appointment of weed inspectors. The inspectors are usually appointed by the council of the municipality, or in special cases they may be appcinted by the Minister of Agriculture in the provincial government. (4) Defines the duties of the inspectors. An inspector may order a farmer to destroy noxious weeds in his fields, but he may order the destruction

A puzzle. How many examples of the ways in which weed and other kinds of seeds are scattered can you find in this illustration?

of a crop only where perennial sow thistle or Canada thistle is present, and then only with the consent of the reeve of the municipality. The cost of destroying the weeds must be borne by the farmer. Inspectors may also prohibit the sale or removal of hay, straw, or grain if it is infested with noxious weeds. (5) Requires that threshing machines and wagon racks must be thoroughly cleaned before being moved from one farm to another. (6) Declares it unlawful to leave screenings containing noxious weed seeds exposed for more than five days at a place where grain has been threshed. (7) Provides heavy penalties for inspectors who neglect their duties, and for persons who obstruct inspectors or fail to carry out orders of the inspectors.

Something to Do

1. How do farmers in your district control weeds? Discuss this important problem with them.
2. Consult weed bulletins, like those suggested on page 241, to learn about the methods recommended in them.
3. Do all you can to keep your school grounds and the adjacent roadsides as free from weeds as possible.

Find information in newspapers and magazines about new chemical weed-killers, such as 2, 4-D. What weeds does 2, 4-D kill? not kill? Where is it useful? not useful?

4. Collect pictures and make drawings to illustrate the various methods of controlling weeds.

5. Who is responsible for the destruction of weeds growing on roadsides? Send to the Field Crops Branch, Department of Agriculture, Regina, for a copy of the Noxious Weeds Act. It is free. Read carefully the section dealing with "Duties of Owners or Occupants of Lands." Study other sections of the act also.

Review Questions and Exercises

1. How can farmers prevent weeds? Explain the importance of co-operation.
2. In controlling annuals, is it the seed or the plant that must be attacked? Why?
3. Briefly outline suitable methods for controlling (*a*) stinkweed, (*b*) perennial sow thistle or Canada thistle.
4. Summarize 6 important sections of the Noxious Weeds Act.

Test your Knowledge

A. List the numbers from 1 to 6 in your science note-book, and after each write the word *true* or the word *false* as you find each of the following statements to be true or false.

1. Growing plants have many enemies.
2. Large plants, such as trees, are not attacked by enemies.
3. Plant diseases are caused by fungi.
4. Covered smut of wheat can be controlled by treating the seed with a chemical, such as formalin.
5. Common scab of potatoes seriously reduces the yield.
6. Crop rotations are an aid in controlling plant diseases that live in the soil.

B. Rewrite each of the following sentences in your note-book, using the words or phrases that correctly complete each statement.

1. The red-backed cutworm lays its eggs in fine, loose, dry soil *in late fall, in late summer, in early spring.*

2. To control the red-backed cutworm, poison bait should be spread over the infested area *early in the morning, just before a rain, on a warm evening.*

3. Grasshoppers are best controlled by the use of *contact sprays such as a soap solution, poison bait, poison sprays.*

4. A solution of *formalin, Black Leaf 40, Paris green* is sprayed on the leaves of potato plants to kill Colorado potato beetles.

5. A cabbage butterfly passes through the following stages in its life-history: *egg, nymph, adult; egg, maggot, chrysalis, adult; egg, larva, pupa, adult.*

6. In controlling annual weeds one should centre the attack on *the plants themselves, the rootstocks, the seeds.*

7. A field infested with Frenchweed should be treated thus: *cultivated in the fall to germinate the weed seeds so that the winter's frost will kill the plants; cultivated early in the fall to germinate the weeds and followed by later cultivation to kill the plants.*

C. Rewrite the following table in your science note-book, rearranging the statements in columns 2, 3, and 4 to match correctly each insect named in the first column.

The red-backed cutworm	is slate gray with yellowish head,	spends from 2 to 4 years in the soil,	and is controlled by a poison spray.
The pale western cutworm	passes the winter in the adult stage,	are frequently found on house plants,	and is controlled by poison bait.
The wireworm	is dark gray with two red bands along its back,	feeds on the leaves of the potato plant,	and are controlled by contact sprays.
The Colorado potato beetle	have sucking mouth-parts,	cuts off the wheat below the ground,	and cannot be controlled by poison bait.
Aphids	is orange-yellow with a hard, shiny body,	comes above the surface at night to feed,	and attacks the roots of plants.

D. State the family and one characteristic of five noxious weeds.

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